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LABORATORY COAL CLEANING STUDIES
OF ALBERTA COALS.

- by -

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A THESIS

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Edmonton, Alberta.

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PREFACE.

The investigation of the cleaning properties of several Alberta coals was carried out in the laboratory of the Research Council of Alberta, under the supervision of Mr. Edgar Stansfield, Chief Chemical Engineer.

This thesis includes a review of coal cleaning processes, the development of testing methods, and the interpretation of the data obtained for six Alberta coals. The term "washing" of coal has been used indiscriminately when referring to cleaning by either wet or dry methods. It is the accepted usage of many authors on account of historical precedence.

The writer wishes to express his appreciation of the kind assistance and many helpful suggestions received from Mr. Stansfield and Dr. A. E. Cameron.

He is also indebted to Professor N. C. Pitcher and Dr. K. A. Clark for discussion and advice, to Mr. W.A. Lang who initiated part of the ash fusion work, to Messrs. Gilbart and Teskey who have assisted in the preparation of this thesis.

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LABORATORY COAL CLEANING STUDIES OF ALBERTA COALS.

CHAPTER I.

ECONOMICS OF THE COAL CLEANING PROBLEM.

Although the coal deposits of Canada are more than ample to supply her own needs, imported coal is extensively used in the central provinces. This condition arises from the location of Canada's coal deposits in the West and East, and the consequent high costs of transportation. While this is largely an economic situation which may or may not be aided by government assistance, it is also true that the winning of these markets may be encouraged in other ways. One of these would be the production of cleaner coal, which, besides being a more merchantable article has the further advantage of resulting in a reduction of freight charges. If this is to become a part solution of Canada's coal problem, then the importance of a study of coal cleaning is evident.

The primary purpose for which coal is cleaned is the reduction of mineral impurities. The inorganic matter in different coals, and therefore the ash left when they are burned, is found to vary notably in amount with the conditions of occurrence and mining. By means of coal cleaning, these differences may be reduced, and from any mine, a standard quality of coal results.

Transportation.

The handling and transportation of useless material in dirty coal represents a loss which might have been reduced by coal cleaning. In 1925,

Lessing computed the railroad loss in hauling ash in Great Britain. He assumed a yearly production of 250 million tons of coal which had an average ash content of about 10% and was hauled an average distance of 43 miles. If the freight rate for this distance was 90 cents per ton, then over 20 million dollars were spent in the transportation of incombustible material. All this material cannot be removed, but considering other losses that accrue from handling and other inconveniences of using raw coal, he states that the country's non-productive yet avoidable expenditure on this account is between ten million and twenty million dollars annually, a waste which is surely worthy of the closest scientific, technical and economic investigation.

In 1924 Vissac[17] estimated that the Crowsnest district in Alberta produced about 2,000,000 tons of coal yearly. If 10% of this amount were eliminated before shipment, then freight reduction of 200,000 tons would be realized and 500 less cars per season would be required. On the same basis of cleaning, with the further assumption that the washery refuse contains 50% mineral impurities, then out of every twenty cars hauling unwashed coal from this district, one of the cars is carrying a useless load.

The following calculations on 100 tons of raw coal containing 10% of removable impurities, illustrates the saving in freight charges resulting from shipping clean rather than dirty coal from Blairmore to Winnipeg. It is assumed that cost of mining is $3.50 per ton, cost of cleaning is 25 cents per ton, and freight charges are $5.20 per ton.

	Cleaned Coal		Uncleaned Coal	
Mining Costs	100 tons	$350.00	100 tons	$350.00
Cleaning "	100 "	25.00	- - - - - -	
Freight	90 "	468.00	100 tons	520.00
Total Cost, Winnipeg	90 "	843.00	100 "	870.00
Per ton, "		9.37		8.70

Since there are other costs resulting from handling a greater amount of material as well as disadvantages in using coal higher in ash, it may be assumed that the value of the 90 tons of clean coal is at least equal to the 100 tons of raw coal, in which case there is a saving of $27.00 in favour of the cleaned product.

Assuming the same mining and cleaning costs, but allowing for an $8.00 freight rate to Ontario, 90 tons of clean coal will cost $1,095.00 as against $1,150.00 for 100 tons of raw coal. In such a case there would be a greater advantage of $55.00 to the credit of the clean coal.

It is thus obvious that the farther coal has to be transported, the greater is the argument in favour of shipping cleaned coal. Although cleaning might be operated with somewhat of a loss at first, yet it seems certain when transportation to distant points is considered along with the advantages in selling a higher quality coal, that wider markets will ultimately follow the adoption of cleaning practice.

Mining and Mechanization.

One of the present developments of coal mining is toward the mechanization of as many manual processes as possible in order to reduce the cost of production. Increase in the use of machinery for cutting and loading coal means an increase in the amount of dirt from roof and floor included in the output. Mechanization may thus make necessary the introduction of cleaning equipment. Such a development has taken place in several mines of the United States.

The installation of cleaning equipment has enabled many mines to obtain satisfactory coal from seams which had been previously considered too high in ash to be worked.

Industrial and Domestic Use.

The use of raw unwashed coal in boiler furnaces often results in an excessive amount of ash on the grate. This lowers efficiency by reducing the draft and increases the danger of burning the grates. Some coals have a lessened tendency toward clinkering when washed.

One of the principal disadvantages in the use of raw coal for domestic purposes is the trouble involved in the disposal of the ashes. Although cleaned coal does not eliminate this inconvenience completely, yet the amount of ash to be handled is reduced and the popularity of the coal increased.

Cleaning has the possibility of increasing the number of coals that may be used for coking purposes, as many concerns will not accept coal for coking if it contains more than 8% ash. Low ash coke is especially desirable for metallurgical work. Cleaning will also normally reduce the amount of phosphorus and sulphur, but fortunately most Alberta coals are low in sulphur content so that this is not important here.

The economic limitations in the way of the development of coal cleaning are principally the costs of establishing and operating the required equipment. Such costs may only be described in a general way, as they vary for each mine and must be settled individually. In many centers, coal cleaning is well established and has proved itself to be sound practice, the advisability of which is never questioned.

Washability tests with a coal are required to show the possible reduction of ash and loss of clean coal. This information is needed before the economic advantages of the purification can be decided.

CHAPTER II.

METHODS OF COAL CLEANING.[15]

Wet methods for cleaning coal have closely followed the development of concentrating devices utilized in the separation of heavy mineral particles from ores. Successful separation is based essentially upon the fact that particles of slate or bone coal have greater specific gravity than clean coal. Because the difference in specific gravity is only slight, practically all methods require close sizing of the products for efficient operation.

Specific gravity is by far the most important property utilized in the separation of mineral aggregates. It functions both in the wet and dry methods of separation, but is probably of more direct importance in the former.

WET METHODS.

1. Specific Gravity.

Trough Washers; The simplest form of washer consists of a slightly inclined trough or sluice fitted with riffled cleats set at intervals along the bottom. Raw coal is fed to the upper end with sufficient water to cause it to move freely; the slate settles to the bottom, and is caught and held in the riffles while the coal passes off the lower end. The device is intermittent for when the riffles have filled with slate the flow of feed has to be stopped and the slate shovelled out. Modifications to give continuous operation consist of continuously moving riffles which drag the refuse into the upper end.

Rising Current Washers: Rising current washers are a direct adaptation of the hydraulic classifiers of ore dressing practice. As is true

in all classifiers, satisfactory separation of unsized feed is impossible. Two types have developed, a launder type washer and a hindered settling classifier. In the launder washer, shallow pockets are arranged at points along the bottom for the introduction of rising currents of water and the removal of slate and heavier particles. Raw coal is fed to the upper end of the launder with sufficient water to cause it to move rapidly. It stratifies the coal by reason of the different specific gravities of the particles so that a layer of slate forms on the bottom, a layer of bone coal next in order, and another layer of relatively pure coal on top. Differences in specific gravity and stream velocities at different depths result in different rates of movement along the trough. The rounded coal particles travel more rapidly in the upper portions of the stream than the flat heavy slate particles at the bottom. On passing over a shallow pocket and slate discharge, the relatively high horizontal component of velocity of the coal particles together with the upward velocity of the rising water from the pocket, cause the clean coal to be carried forward down the trough while the slower moving slate particles fall through the slot against the ascending current of water. One of the best known washers of this type in use at the present time is known as the Rheolaveur.

The second type of rising current washer is essentially a hindered settling classifier in which sized raw coal in a carrying current of water is fed into a tank against a rising current of water. The heavy particles of slate settle against the current and are discharged at the bottom while the lighter coal particles are lifted and pass out at the top. In some cases, such as the Jeffrey-Robinson washer, a stirring mechanism is introduced to prevent the material from packing and channelling at the end. The Draper washer is of the hindered settling type and has found considerable use in

cleaning practice.

Jigs. Jigs are widely used as a means of separating out the heavier particles of slate from raw coal. They are essentially machines utilizing the differences in the falling rate of particles of varying specific gravity and sizes in a semi-fluid mass of solid particles suspended in water. They consist of a screen supporting the material to be separated in the form of a bed that is brought into partial suspension at regularly recurring intervals by various means equivalent to a current of water forced upward through the screen. Following suspension, the bed comes again to rest on the screen either by settling under the action of gravity alone, or aided by the subsidence of the water. The water currents are brought about either by moving the screen in a tank of water or by moving the water through the screen. After a few repetitions of the pulsation-subsidence cycle, distinct stratification of the particles on the screen is effected, grading from heaviest at the bottom to lightest on the top. Final separation of the material on the screen is obtained by skimming off the surface layers, (which in the case of coal will be the clean coal) and collecting the lowest layer either mechanically or by manual means.

If the up and down strokes of the jig are not suitably regulated, suction will largely destroy the stratifying effect by causing the smaller and lighter particles to be carried back and remixed with the others on the return stroke. To overcome this trouble, the Luhrig washer uses a piston activated by a cam such that a slow return stroke is obtained. Flat pieces of feldspar are often placed on the screens of fine washers of this type to minimize the effect of suction. The Baum washer uses compressed air controlled by a valve in place of the piston such that an accelerated up current

and a retarded down current is easily obtained. The Baum washer operates successfully in cleaning coal of very wide sizing limits at one operation.

Reciprocating Tables. Reciprocating tables consist substantially of plane surfaces inclined slightly from the horizontal, shaken with a differential movement in the direction of the long axis and washed at right angles to the direction of the motion by a thin film of water. The tabled deck may be partially or wholly riffled, the riffled grooves generally growing shallower towards the concentrate end. Each particle on the inclined surface of a table in operation is under the influence of the force of friction or adhesion between the deck and the particle and the pressure of the moving water. The particle tends to move in the direction of the resultant of these forces. If the table is riffled, the particles tend to stratify according to specific gravity between the riffles, with the result that these riffles have a greater effect in restraining the downward component of the motion of the heavier particles. Thus the heavier particles are carried to one side of the table while the lighter particles are washed off the lower side. Examples of this type of cleaning device are to be found in the Wilfley, Deister-Overstrom and Wye tables.

2. Heavy Fluid Methods.

The specific gravity of coal matter is comparatively only slightly greater than that of water. Impure coal consists of this light coal matter intimately mixed with mineral substances having specific gravities appreciably in excess of that of water. Mixtures of the two form aggregates which will vary in specific gravity from that of essentially pure coal (about 1.3) to that of material such as clay (above 2.5). It is therefore possible to make separations by bringing the unsized crushed material into contact with fluids of specific gravity intermediate to these figures. This is the basis

of heavy fluid separations. The fluids themselves may be produced by increasing the specific gravity either from the suspension of finely divided mineral matter in the water or by forming solutions with heavy salts. This latter principle covers the essential methods of studying the washability of coals.

Commercial methods utilizing these principles have been developed in recent years. In the Chance separation process, the separation of the slate from the coal is effected by a fluid mixture of sand and water flowing upward in a conical vessel, the contents being agitated by mechanical means. The effective specific gravity of the fluid can be made to vary from 1.3 to 1.8 and thus a separation brought about. Crushed but unsized coal is placed on the surface of the fluid. The lighter material or the clean coal, overflows the periphery of the tank, while the heavy material settles against the slowly rising sand-water fluid, and is removed from the bottom. The pulverized solid whose suspension raises the apparent specific gravity of the fluid mass consists of particles smaller than the average size of the particles to be floated, and are of greater specific gravity. Maintenance of the specific gravity of the predetermined fluid mass is the important and difficult part of the operation since the added solid is lost by overflow and the liquid becomes contaminated by fine particles of float and sink materials.

Very recently R. Lessing[20] has shown that it is possible to use solutions of heavy salts for separating coal on a commercial scale. The liquid used is a solution of calcium chloride at a density of 1.4. By an ingenious method of surface replacement, the salt is nearly all regained by washing and may then be concentrated. This cleaning system is expensive and requires a

great deal of water, but its efficiency is very high as far as loss of clean coal is concerned.

DRY METHODS.

Dry methods are processes in which water is not used as a carrying medium, but the coal moves on, to and from the machines by the forces of gravity alone. All dry methods have the fundamental disadvantage that they produce dusty conditions within the plant, but under certain climatic conditions such as where the product of the cleaning plant has to be shipped in weather below freezing, such methods have to be utilized.

1. Pickers.

Hand Picking. Hand picking or hand sorting is the manual removal of lumps of waste from the coal as mined. Sorting of some kind is a part of every mining operation and starts within the mine itself where the miner discards into the gob pieces of roof and floor that have been unavoidably broken during the mining operations. Picking is also done on the surface from travelling belts or screens during the process of sizing run of mine coal. In many instances the process of screening is an active factor in cleaning as flat pieces of shale may pass easily through bar screens while the rounded particles of usually cleaner coal is retained. A certain amount of sorting results from screening in that the shale breaks into tabular pieces and is often found concentrated in certain of the sizes.

Mechanical Pickers. Many pickers have been developed to take advantage of the difference in shape between the pieces of coal and the pieces of slate. The cubical fracture of the coal tends to give rounded or sub-angular forms, whereas the broken slate is flat and tabular. The rounded form allows rolling while the flat fragments of slate slide more slowly on

an inclined surface. This property is made use of in troughs or spiral separators. The coal particles travel faster down the slope and will jump a gap in the trough bottom, while the slow moving particles of slate are caught and separated out in this manner. In the spiral picker, the rounded or sub-angular forms of coal work to the outer periphery on account of the action of both gravity and centrifugal force.

2. Pneumatic Machines.

Air issuing from a porous surface under pressure or fluid mixtures of air and finely divided mineral matter under properly regulated conditions of agitation, can be made to act in a similar manner to water or aqueous solutions. This fact has been made use of in the development of dry cleaning equipment, which has met with considerable success in recent years.

Air-sand Process. The air-sand process as developed by Fraser and Yancey is a float and sink method of separation in which the separating medium is fine sand supported on a porous medium and maintained in a semi-fluid state by means of air forced through the sand. The effective specific gravity is kept intermediate between that of the clean coal and the slate or bone coal, by adjustment of the air pressure.

Pneumatic Tables. Pneumatic tables for treating coal developed from similar equipment used for cleaning seeds and cereals. Air issuing from a canvas or woven-wire riffled deck surface tends to lift the lighter coal particles. When this effect is combined with the agitation of the table, sufficient fluidity is imparted to the mass to permit of separation.

FROTH FLOTATION.

This system of separating materials was originally developed for use in ore dressing. It was first applied to coal cleaning in

1920 in Spain and France, and since that time has obtained considerable popularity, particularly in the cleaning of fine coal.

It depends essentially upon the different wettabilities of coal and dirt by water. Coal has a lower wettability than that of the dirt and so may be floated off while the dirt sinks. Eucalyptus oil, turpentine, and other reagents are used to induce bubble formation and to stabilize the froth produced. Such a condition of the separating medium increases the liquid-air surface so that a large area may be obtained in a small tank. There are many types of froth flotation washers. One of the best known is the Elmore vacuum flotation process in which a vacuum is created in the separating tank to produce the frothing.

CHAPTER III.

IMPURITIES OF COAL RELATED TO COAL CLEANING.

According to accepted theory, coal has originated from peat beds transformed by geological actions. The silt, clay, or other material with which the peat was covered, became associated with it to a greater or less degree as impurities. Other impurities entered the coal by means of infiltration.

From the view point of a coal washing problem, these impurities so formed may be classified as either disseminated or localized. Disseminated impurities are those which are structurally an intimate part of the coal. There are many gradations of disseminated impurity in different coals, ranging from clean coal with impurities largely of plant origin, to carbonaceous material containing such a large quantity of inorganic substances that it has little value as fuel. Infiltration may be responsible for the presence of calcite, gypsum, iron and magnesium carbonates as disseminated impurities.

Localized impurities are those particles of material largely composed of mineral matter. As such they may be loose pieces of shale, rock, pyrites or other heavy materials. When the impurities are easily broken from the coal, they are known as partings, but sometimes they adhere closely and are termed binders. Particles of coal containing large amounts of localized impurities are easily removed by cleaning methods since they have a higher specific gravity than that of the clean coal.

The total amount of impurity in the coal is generally considered to be proportional to the percentage ash left when the coal is burned. During the determination of ash, chemical changes take place such that the weight of

the ash is usually less than that of the original impurity. Stansfield and Sutherland[13] have determined a factor for calculating the percentage of mineral matter from the percentage of ash and have found that for Alberta coals it generally lies within the limits of 1.08 to 1.19. As far as the interpretation of washing results is concerned, the direct percentage of ash offers a satisfactory comparative basis for estimating the degree of cleaning.

Specific gravity, size and shape are the principal properties made use of in separating coal from its impurities. The apparent specific gravity of coal is a variable quantity which depends to a certain extent upon the nature of the coal, but principally upon its mineral impurities. The apparent specific gravity may be found by weighing lumps in air and in water, and a number of determinations on Alberta coals have been made in this manner. This procedure gives what is known as the apparent specific gravity and includes the effects of porosity and moisture content. This is the significant value as far as cleaning operations are concerned.

When the apparent specific gravities and ash percentages of a series of lumps of a given coal are expressed in graphical form, a linear relation is usually found showing that the specific gravity of the lump is closely proportional to the amount of mineral impurity. One may obtain from this graph the approximate specific gravities of lumps of the coal having various degrees of impurity, and by extrapolation, the specific gravities for pure coal.

In the following table is shown the specific gravities of various representative coals for 5 and 10% ash.

TABLE I.

Coal	Pure Coal 0% ash	5% Ash	10% Ash
Sub-bituminous	Specific Gravity	Specific Gravity	Specific Gravity
Lethbridge	1.28	1.32	1.37
Pincher	1.27	1.30	1.34
Magrath	1.29	1.34	1.36
Saunders	1.29	1.32	1.36
Coalspur	1.27	1.33	1.40
Minehead	1.31	1.35	1.39
Average	1.29	1.33	1.37
Bituminous			
Coleman	1.26	1.28	1.35
Bellevue	1.26	1.31	1.37
Brule	1.23	1.29	1.37
Hillcrest	1.24	1.30	1.36
Mountain Park	1.24	1.31	1.34
Luscar	1.23	1.31	1.39
Brazeau	1.27	1.31	1.36
Average	1.25	1.30	1.36
Anthracite			
Anthracite	1.29	1.36	1.42

It will be seen that the difference between any coal of 0% ash and the same coal of 10% ash, is usually greater than the differences between any two coals of zero ash. The average increase in specific gravity for each 1% of ash for sub-bituminous coals is .008, for bituminous coals, .011, and for anthracite .013.

Porter and Durley[7] concluded as a result of their investigation of Canadian coals that there are few, if any, worth burning, so dirty that they have a specific gravity over 1.6; and that, excepting the anthracites and one or two special types of coals, the approximate limit for commercially

profitable coals is 1.55. They also stated that Canadian bituminous coals would have a specific gravity between 1.265 and 1.325, if pure. From a similar quotation in the same book it is not clear whether pure coal of zero ash is meant, or pure coal which still contains a small percentage of innate ash.

CHAPTER IV.

THE WASHABILITY TEST.

The purpose of the washability test may be summarized as follows:

(1) To decide the reduction of ash to be attempted and the nature of the products most suitably prepared from the coal.

(2) To provide information that will decide the cleaning process most suitable for the coal, or to check the efficiency of existing plant conditions.

Sampling.

If washing tests are to be reliable, it is important that a representative sample be secured. The amount of sample required varies proportionately with the size of the coal examined. Blythe and O'Shea[4] worked out a relation in which they found that a minimum number of 2000 pieces of coal was required to keep the mean probable error below 0.5%. On this basis the recommended amounts according to size are:

Size (in.)	Weight
Under 1/8	30 gm.
1/8 to 3/8	400 gm.
3/8 to 5/8	2,000 gm.
5/8 to 1	32 lb.
1 to 2	2 cwt.
Over 2	4 cwt.

It is sometimes sufficient to take a single sample and crush the whole down to pass $\frac{1}{4}$ inch and make one series of float and sink tests for the overall size. While this is economical of time and labour, much valuable information may be lost in studying the relative cleaning properties of the different sizes. This phase of the subject is discussed more fully in the section on screening.

Henry Tube.

In this method of testing the washability of coal, the sample is

placed in a long tube of suitable proportions and jigged up and down for fifteen minutes. At the end of this time the heaviest particles will have settled to the bottom with the particles of decreasing specific gravity in ascending order. The column of coal is pushed out and slices are taken off at regular intervals. The ash analysis of these layers and their weight provide the necessary information for the construction of a washability curve. Each layer may be considered as a separate "float" fraction similar to those obtained by float and sink tests, and the results are employed in exactly the same way. The results obtained by this method depend considerably upon the technique of the operator, and considerable judgment is required to divide the bed into slices which will give a satisfactory graphical representation. The method is generally regarded with less favor than float and sink tests with heavy solutions.

Heavy Solutions.

The second method of testing washability of coals is by means of a series of heavy solutions. When the sample is placed in the liquid of suitable specific gravity, the coal whose specific gravity is lighter will float, while that which is heavier, sinks. The test may be repeated using a number of these solutions in the same manner, thus obtaining the specific gravity distribution of the material in the coal. As shown previously, the percentage of ash in the fractions is closely proportional to their mean specific gravity.

Heavy solutions may be of two kinds; (1) water solutions of inorganic salts, etc., and (2) organic liquids alone or in mixtures. Benzene is the diluent commonly used. Solutions of the first type are generally less expensive but are more troublesome on account of the thorough washing

necessary to remove the last traces of them from the coal samples. The organic solutions have superior wetting properties and hence are preferred for separations with fine coal. They have the further advantage of evaporating easily from the coal after use.

Their properties may be summed up as follows:

Solution	Specific Gravity Range	Remarks
(1) Inorganic solutions in water.		
Calcium chloride	1.00 - 1.42	Least expensive - used in K.& T. and similar apparatus
Calcium nitrate	1.00 - 1.55	Higher range than calcium chloride
Zinc chloride*	1.00 - 1.80	Unsatisfactory because of acid properties, also expensive, but largely used nevertheless.
Sulphuric acid*	1.00 - 1.89	Affects the mineral constituents of the coal - troublesome to use.
(2) Organic Liquids.		
Benzene	0.89	Only used in mixtures.
Carbon tetrachloride and benzene	0.89 - 1.59	Least expensive of heavy organic solutions.
Chloroform* and benzene	0.89 - 1.50	Has objectionable fumes.
Bromoform and carbon tetrachloride	1.59 - 2.88	Expensive, but convenient for separations over 1.6 s.g.

* Not used during this investigation.

The factors tending to change the specific gravities of the heavy solutions are:

(1) Evaporation on exposure to the atmosphere.

(2) Changes in temperature.

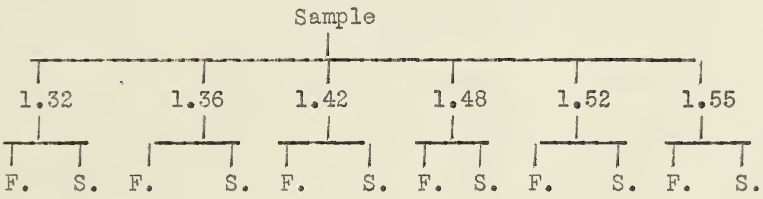
(3) The dilution of the solution by moisture from the coal.

The organic solutions described evaporate very readily. The carbon tetrachloride evaporated at a slightly greater rate than the benzene from the mixtures employed so that they tended to decrease in specific gravity. With regard to the second factor, the room temperature should be kept as constant as possible to avoid consequent changes in the densities of the heavy solutions. As far as the third factor is concerned, dilution of the solution was unimportant as only low moisture coals were tested. When coal wet by one solution is placed in another of different density there is a slight change in the specific gravity of the solution, but the change is not great if the quantity of the second solution is fairly large. In all cases the specific gravity must be checked carefully with an accurate hydrometer before separations are made, and after if there is possibility of change from excessive evaporation.

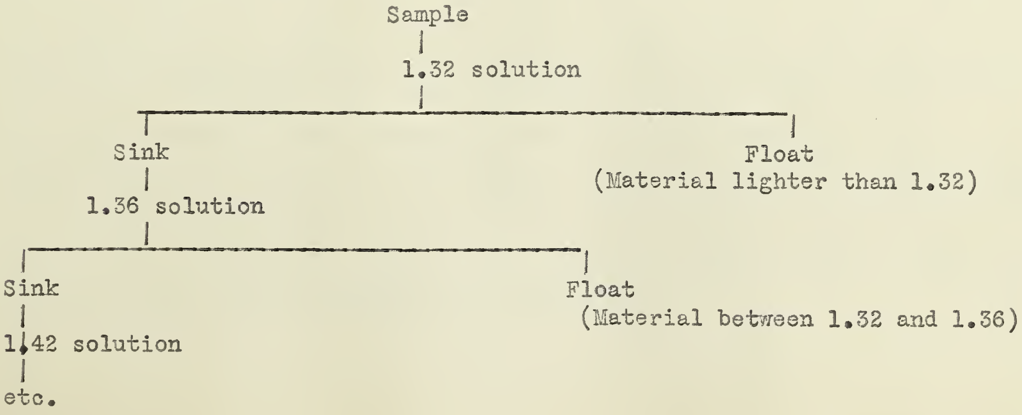
Those particles of coal whose mean density is near that of the solution (middlings), will have a tendency to remain in suspension, especially if they are of fine size. There is also some possibility of small coal remaining at the surface of the liquid if it is not thoroughly wet, as dry coal may float even if heavier than the solution. Too much coal will produce layers of such thickness that particles of float or sink may be trapped in the wrong layers. These difficulties may be largely overcome by stirring and jigging where possible, followed by a prolonged period of settling or centrifuging.

Methods of Float and Sink Analysis in Heavy Solutions.

The relative proportions of the light and heavy material in a coal may be determined, or what is often known as its specific gravity analysis may be made, by either of two general methods of procedure. By the first method the sample is divided into as many parts as there are solutions to be used. Each part is placed in its respective solution and float and sink fractions thus obtained from each. These are individually weighed and analysed for ash. If six solutions are used, twelve float and sink fractions result, i.e.



In the other process the undivided sample is placed in the lightest solution and the float is collected. The fraction sinking is then placed in the next solution of higher specific gravity and the process repeated. A succession of floats are thus collected, leaving a final sink from the heaviest solution. The weights of the fractions so formed and the ash analysis of each may be calculated to the same basis as those from the first method, if desired.



Relative Advantages of the Divided and Unit Sample Methods.

The advantages of the divided method are:

(1) The results are already expressed on a practical cumulative basis without the extensive calculation necessary in the other method.

(2) From the percentage weights and analyses of the floats and sinks for each solution one may derive the original ash in the raw sample and thus check the accuracy of each stage of the work.

(3) The percentage of material lying between any pair of specific gravities or the specific gravity distribution, as directly found by the unit sample method, may easily be obtained from the data of the divided sample procedure by subtracting the percentages of floats.

The advantages of the second or unit sample method are:

(1) Less sample is required. If six solutions are used, then several times, although less than six times, as much sample is required by the first method to keep the possibility of error below the desired limit.

(2) The number of samples for moisture and ash analysis is reduced by nearly half using the unit sample method.

(3) Since a smaller amount of coal is separated than by the first method, there is a smaller loss of solution.

The two methods may be further compared by considering the ease of separation in the case of light coals or heavy coals. The divided method presents no difficulty with either type, but the unit sample method has an advantage of greater ease of separation when dealing with very light coals. If the coal is so light as to have 80% or more as float in the first solution, a small yet sufficiently representative amount of coal is left as sink to be dealt with in the remaining heavy solutions.

CHAPTER V.

PROCEDURE USED IN WASHABILITY TESTS.

The amounts of samples used were made to conform, as far as possible, with the table of amounts as originally developed on a rational basis by Blythe and O'Shea (Chapter IV). It has been recommended that only one type of solution be used for all the separations, but as this was not practicable, a series of solutions was adopted for the various specific gravities and methods. When fine coal was to be separated, it was found advisable to use organic solutions, while for sizes above 8 mesh (Tyler screens), involving the treatment of large samples, inorganic solutions were employed for the sake of economy. The inorganic solutions were: - 1.32, 1.36, and 1.42, calcium chloride; 1.48, 1.52, and 1.55, calcium nitrate. Organic solutions of the same specific gravities were prepared by mixing carbon tetrachloride and benzene. The specific gravity range was extended to 1.59 by using carbon tetrachloride alone, and to 1.8 with bromoform and carbon tetrachloride.

The coal separated by means of inorganic solutions was left in running water until it was certain that all traces of the heavy solution had been removed, after which it was dried on a steam table. The coal treated with organic solutions needed only to be exposed to the atmosphere for some time, preferably on a steam table or some other warm place. The fractions after drying were weighed to obtain the relative proportions of float and sink, and then analysed for moisture and ash by the A.S.T.M. methods[2].

Beaker Method.

This procedure may be used for all sizes of coal, although with increasing difficulty in the finer sizes. The sample is stirred in a beaker with the liquid of the desired specific gravity and allowed to settle. The

float is skimmed off the heavy solutions, care being taken to prevent the mixing of float and sink. Since the fine sizes require a considerable period of settling by this method, precaution is usually taken to prevent evaporation when organic liquids are used. Some experimenters have carried out the process in a stoppered bottle and removed the fractions through a glass tube by suction.

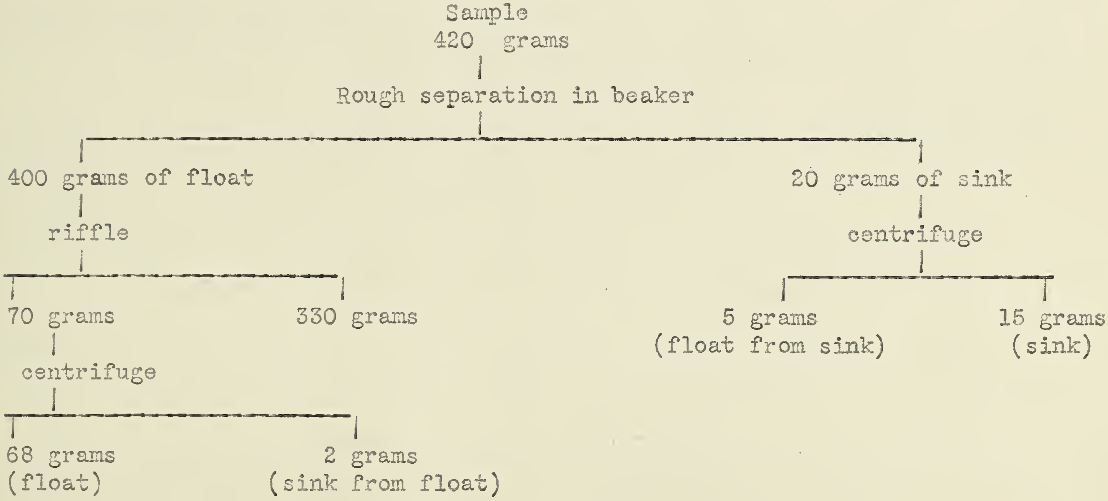
Centrifuge Method.

Centrifuging may be used to give sharper separations of fine coal in heavy solutions and to shorten the time. The method employed in this laboratory makes use of centrifuge cups[1]. These cups consist of brass cylinders, $6\frac{1}{4}$ inches long and 2 inches in diameter, closed at the bottom and fitted with a cone constriction at the middle. A cone valve is supported in the middle of the constriction by means of a screw-cap at the top, and may be closed by screwing down into the constriction. This gives a positive cut-off between the float and sink, and avoids the risk of mixing the fractions.

Thirty-five grams of coal is placed in each of two cups partly filled with the heavy solution of the desired specific gravity. The mixture is stirred and allowed to settle for a few moments, and then the cone valve is placed in position but not closed. The two cups are nearly filled with the solution, care being taken to equalize their weights, and centrifuged for 15 minutes at 900 r.p.m. in a size 2 centrifuge made by the International Equipment Co. The valves in the cups are then closed without disturbing the fractions. The floats are washed out into a Buchner funnel by means of some of the same solution, and filtered with suction. The sinks are treated in a

similar manner. After allowing the heavy organic solution to evaporate, the fractions are weighed and analysed for ash. If inorganic solutions were used the coals would be thoroughly washed and then dried before weighing.

Some difficulty was experienced in obtaining large enough samples of sink where the amount of float was over 90% of the sample, as the above procedure involved a great deal of labour, and only 35 grams could be treated in a cup. If 15 grams, or more, of sink were desired for analysis, and approximately 95% of the sample floats, then about 400 grams of coal would be required. To avoid centrifuging this amount of coal, a rough separation into floats and sinks was first made in a beaker, and the resulting fractions then centrifuged. The procedure is illustrated by the following result with 420 grams of coal which contained 93.8% of float.



The percentage of floats and sinks for the 420 grams of coal may be easily calculated proportionately from the last four fractions. Representative ash samples for analysis are obtained by combination of the last four fractions. 70/400ths of the 5 grams of float from sink are added to the 68 grams of float. Since all the 15 grams of sink is used, all the sink from

330 grams of float must be added to it.

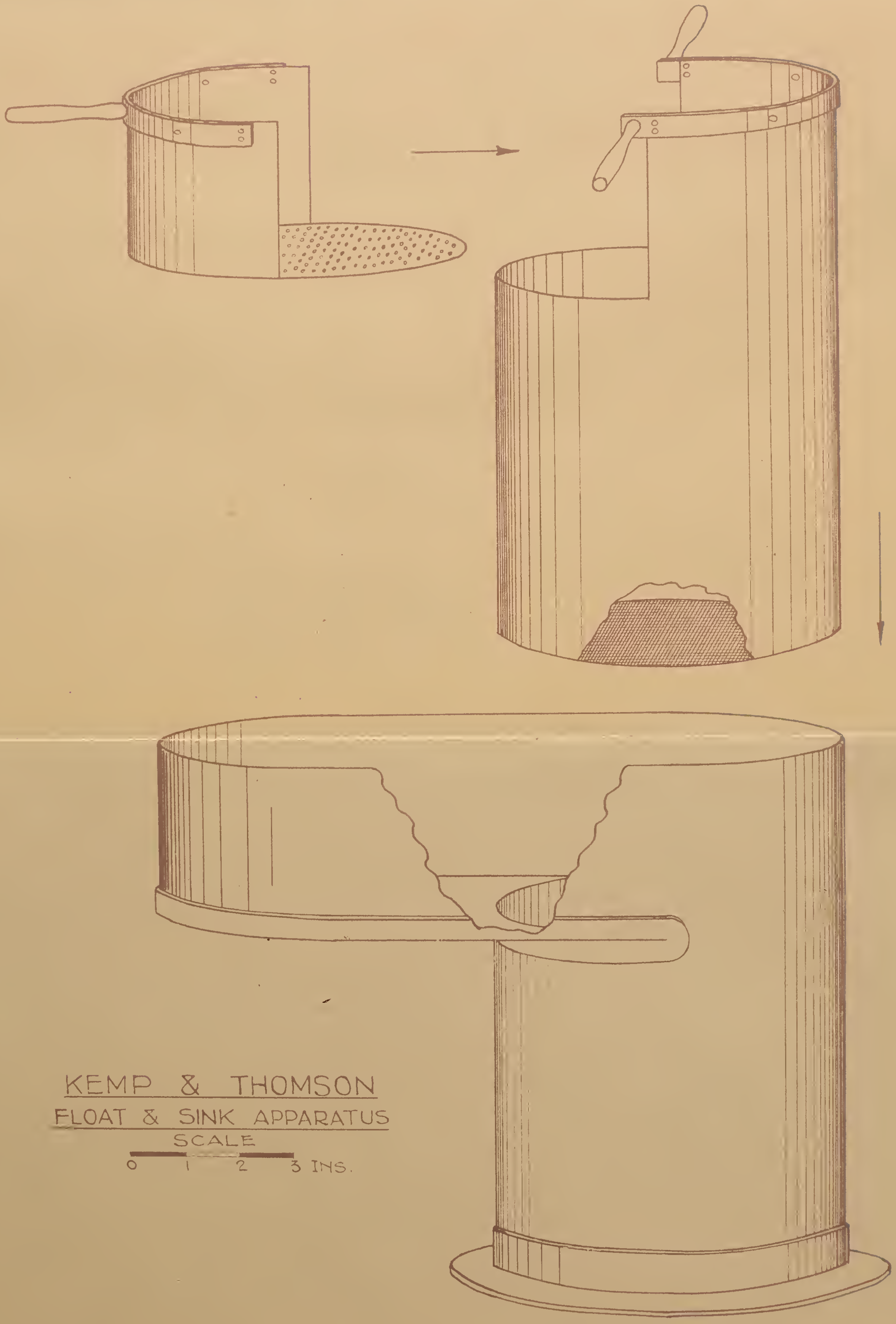
Ash analysis showed that there was not a great difference of per cent ash in the float and the float from sink, or in the sink and the sink from float. The Mountain Park, Luscar, and Coleman fractions for ash analysis were combined, regardless of proportional amounts, but accordingly the error in per cent ash was not considered sufficiently great to affect washability determinations.

The separations of float from sink in fine coal is a difficult matter with many methods. The method of separation in centrifuge cups is simple and accurate. However, if a large quantity of coal has to be handled and the preliminary beaker treatment is used, a great deal of routine work is involved.

Kemp and Thomson Apparatus.

This equipment consists of a central float and sink container connected by a system of pipes and valves to a series of six bottles holding solutions of different specific gravity. The liquid in any bottle can be raised by means of air pressure and thus forced into the vessel on top.

The device in which the separations are made consists of three parts, an outer container, an inner vessel or jig, and a scoop. The container is cylindrical in shape, 6 inches in diameter and 10 inches in height. A trough 6 inches long and 3 inches deep is attached to the side of the container at the top. A cylindrical jig fits evenly into the container and is fitted with a sieve at the bottom and a pair of handles at the top for raising and lowering. The jig is cut away at the top on one side so that according to the way it is turned, the jig and container make a complete cylinder, or one side is open in such a way that a flat bottomed scoop may



KEMP & THOMSON

FLOAT & SINK APPARATUS

SCALE

0 1 2 3 INS.

RESEARCH COUNCIL OF ALBERTA - FEB 1950

be moved into it from the trough.

The coal is placed in the jig arranged so that the entrance to the trough is blocked by the remaining top half of the side. The heavy solution selected is forced from its bottle up into the container and allowed to fill it and the trough. The coal is first stirred to ensure complete wetting. It is jigged to assist the separation into float and sink, then allowed to stand to complete the separation. The jig is turned and the scoop moved in to gather and remove the particles of float. The sink is removed from the jig or allowed to remain and to be treated with the next heavy solution according to the unit sample procedure. The samples of float and sink so obtained are then washed, dried, and weighed.

Separations may be made very quickly and efficiently with this apparatus for the sizes of coal between 1 inch and 1/8 inch diameter. It is not suitable for finer coal on account of the trouble involved in gathering the float and the difficulty of keeping the fines out of the solution bottles.

CHAPTER VI.

REPRESENTATION OF WASHING DATA.

The numerical data obtained from washing tests are usually represented in graphical form and the resulting curves are known as washability curves. Their construction and their use in determining the washability of a coal was first suggested in 1903 by Charvet.

Two washability tests, one by the unit sample method, and one by the divided sample method, have been made on the same sample of Brazeau coal, size -1" + ½". The data obtained by these methods are used in this chapter to illustrate two types of washability curves, yield-ash curves, and yield-gravity curves.

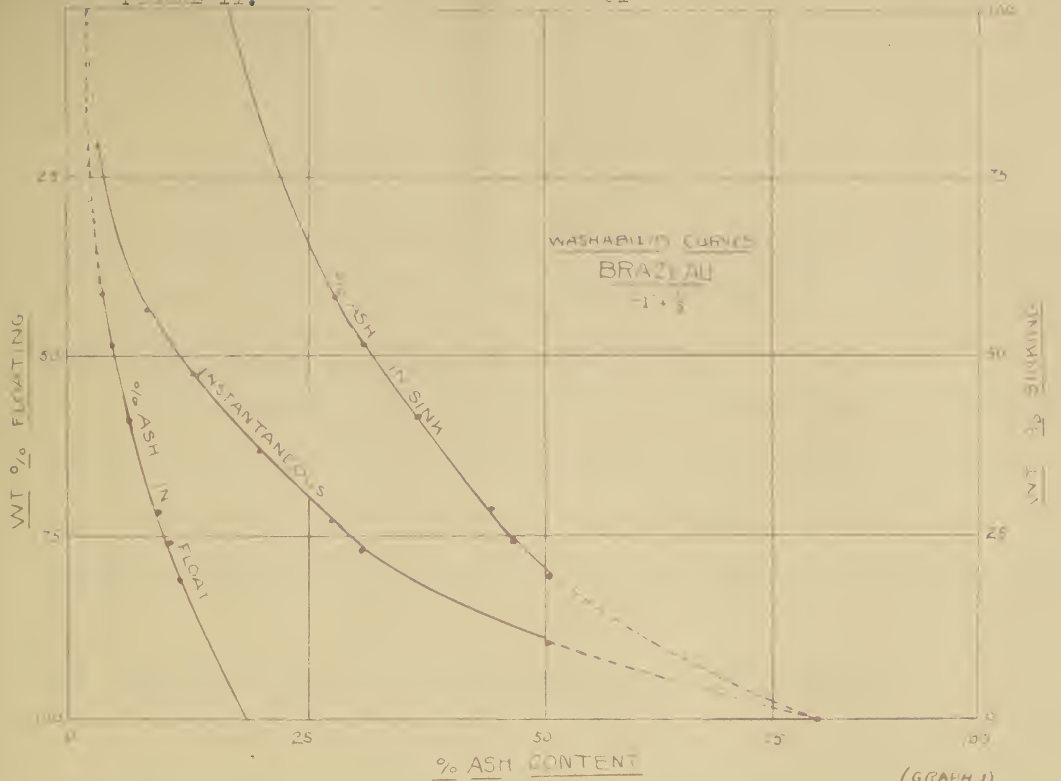
(1) Washability Tests by the Unit Sample Method.

The data obtained by this method are given in the following table.

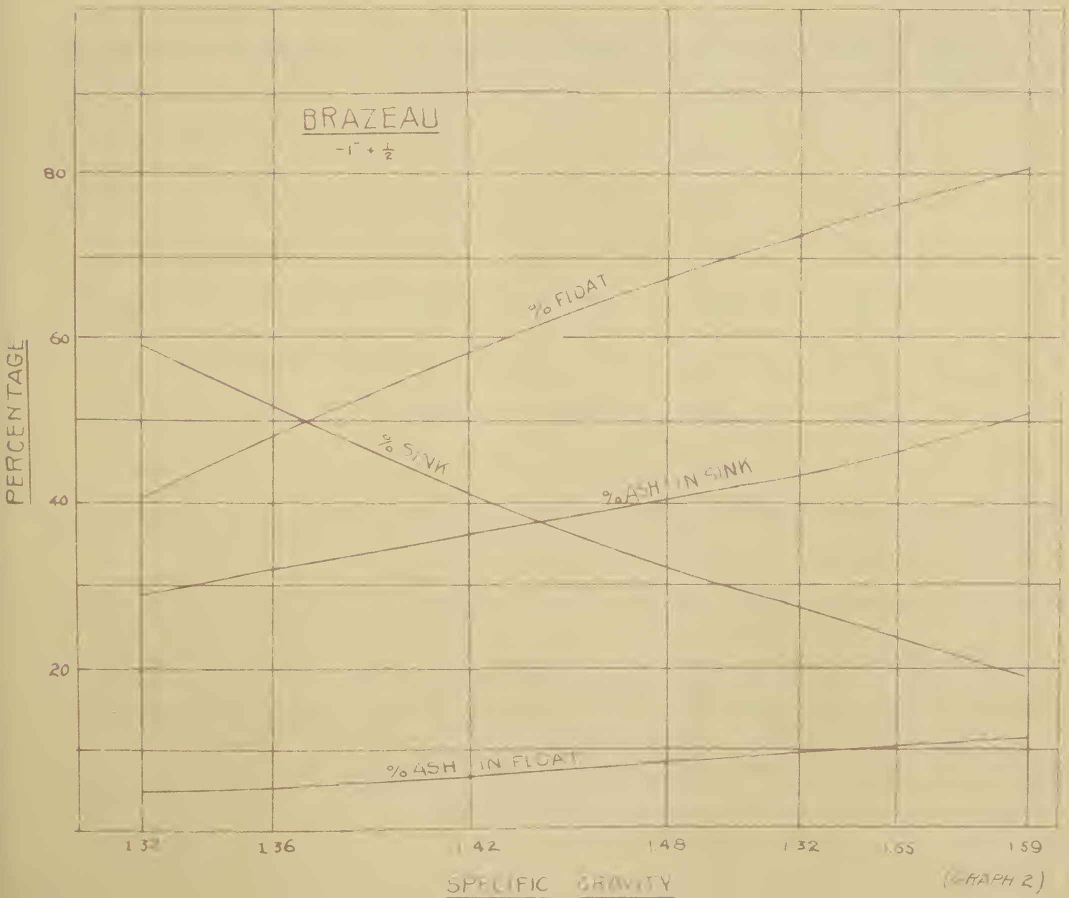
Original Data			Sp. Gr.	Deduced or Cumulative Data		
Sp. Gr. of material	% Wt. of Fraction	% Ash in Fraction	of Solution	% Wt.	% Ash in Float	% Ash in Sink
Less than 1.32	40.4	4.46	1.32	40.4	4.46	28.55
1.32-1.36	7.9	8.04	1.36	48.3	5.04	31.65
1.36-1.42	12.5	13.95	1.42	60.8	6.88	37.30
1.42-1.48	7.0	19.85	1.48	67.8	8.21	41.10
1.48-1.52	4.4	24.93	1.52	72.2	9.21	43.75
1.52-1.54	3.1	27.10	1.54	75.3	9.97	45.75
1.54-1.6	5.6	29.95	1.6	80.9	11.36	50.21
Over 1.6	19.1	50.21		100.0		
Total	100.0	18.81				

The cumulative data is calculated from the original data. The

FIGURE II.



(GRAPH 1)



(GRAPH 2)

cumulative ash in float is calculated by taking cognizance of the weights and ash in the separate floats up to the point in question. Thus 40.4 parts of float with 4.46% ash and 7.9 parts with 8.04% ash will give 48.3 parts with

$$\frac{(40.4 \times 4.46) + (7.9 \times 8.04)}{48.3} \times 100 = 5.04\% \text{ ash.}$$

The cumulative ash in the sink is calculated from the weights and ash in the float and sink fractions subsequent to the point in question. Thus 7.0 parts with 19.85% ash, 4.4 with 24.93%, 3.1 with 27.10%, 5.6 with 29.95%, 19.1 with 50.21%, gives 39.2% with, by a similar calculation, 37.30% ash.

(2) Data for Washability Tests by the Divided Sample Method.

The data showing the float and sink result for Brazeau coal, size -1" + ½", by the divided sample method, are given in the following table:

Specific Gravity	% Float	% Ash in Float	% Sink	% Ash in Sink	Calculated % Ash for sample
1.32	40.8	4.99	59.2	28.63	19.0
1.355	48.3	5.47	51.7	34.02	20.2
1.42	58.3	6.98	41.7	38.41	20.1
1.48	72.7	8.67	27.3	45.65	18.8
1.51	73.3	9.14	26.7	44.70	18.6
1.55	77.3	10.05	22.7	49.60	19.0
				Average	19.3

The accuracy of these figures is easily checked by calculating the original ash of the portions taken from the four values at any specific gravity. Thus 40.8 parts with 4.99% ash and 59.2 parts with 28.63% ash represent 100 parts with 19.0% ash. It will be noted that the range of ash values in the last column is from 18.6 to 20.2. This is probably largely

explained by difference in ash content of the separate portions, and the figures may be taken as a reasonable check on the accuracy of the work.

Yield-ash curves.

These curves have been illustrated with the data from the unit sample method. Two direct curves and one derived curve may be drawn from the cumulative data in the above table, as shown on page 31, graph 1. The percentage ash in float curve is obtained by plotting the cumulative percentage float against tho cumulative percentage ash in float. Similarly, the percentage ash in sink curve is formed by plotting the cumulative percentage sink against the cumulative percentage ash in sink. The percentage ash in float curve for zero % floating has been shown at about 2% ash. It is only known that it is less than 4.46% and represents the ash in particles of coal whose ash cannot be reduced by any amount of washing. The curve then increases to 18.81% ash at 100% float. The percentage ash in sink curve begins at 18.81% ash for 100% sink, and increases to a point between 80 and 100%. The position of this latter point was not **determined.** It represents the ash left on the ignition of the mineral matter, and is known to be about 90% for the ordinary impurities in Brazeau coal.

The derived curve which is the middle curve in the same graph, is known by various names as "instantaneous", "elementary", "actual", or "observed". It shows the percentage ash content of the material highest in ash which is included with any particular float. It is computed as follows:

If coal were placed in water, for example, and salt added to bring the specific gravity slowly up to 1.32, successively heavier and heavier particles would float until a total of 40.4% floated, as already stated. It is assumed that at the middle point, i.e. with 20.2% floating, particles with the average ash, i.e. 4.46%, just float. The fraction of coal heavier than

1.32 specific gravity and lighter than 1.36 specific gravity is 7.9% of the total weight. The average percentage ash of the clean and dirty particles in this fraction is 8.04%. A particle having this average ash content will be found floating at a yield half-way between the upper and lower limits of this fraction, namely 40.4 + $\frac{1}{2}$ (7.9) or 44.3%. Points are plotted for as many heavy solutions as were used, and the curve continued until it meets the lower horizontal axis with the percentage ash in the sink curve. If very few solutions are used, this "average ash content of the specific gravity fractions" curve is likely to be very inaccurate, but the more solutions used, the more accurate becomes the curve.

These three curves are the most commonly used washability curves, and are of much assistance in coal washing problems, as they show the relation between the percentage of ash in the fractions and the yield or percentage recovery. For a 75% yield of clean coal these curves show that:

(1) the ash in the clean coal would be about 10%;

(2) the ash in the refuse or discard would be 45%;

(3) the ash in the dirtiest particle of coal in the clean coal would be about 30%.

Increasing difficulty of separation is indicated at that point on the ash in float curve where it flattens out parallel with the vertical axis. This tendency shows that a large reduction of yield barely influences the ash. The percentage ash in the float curve for the Brazeau sample has a fairly uniform slope with the absence of such a defined point.

Yield-gravity curves.

These curves have been illustrated with the data from the divided sample method, although either method can be used for either type of curve.

On page 31, graph 2, are shown the following specific gravity curves obtained by plotting the divided sample data; (1) % Float, (2) % Sink, (3) % Ash in Float, (4) % Ash in Sink.

The nearer horizontal any section of the percentage float curve may be, the greater can be the reduction of ash with small reduction of yield. On the contrary, a steeply inclined portion would indicate a small reduction of ash involving a large reduction of yield.

Comparison of Washability of Different Coals.

If the specific gravity distribution of two coals is the same, then the difficulty involved in cleaning will be the same, provided that the other factors such as size and shape of particles are also similar.

It is possible from washability curves to compare to some extent the feasibility of washing different coals. In the commercial cleaning of coal by any method it is generally found that one fraction is obviously clean coal. Another fraction is so dirty that it must be discarded. A third fraction, commonly termed "middlings" is too dirty to be satisfactorily included with the clean coal and yet contains too much coal to be economically discarded. The larger the proportion of this third fraction, the more difficult it is to clean the coal. In the washability curves, the middlings consist of particles whose gravity lies close to the gravity at which it is desired to make the cut between clean and dirty coal.

A direct comparison cannot always be made since the specific gravities corresponding to the point of cut in the commercial operations vary from mine to mine. The proportion of shale or other rock present affects somewhat the percentage ash of the sample and the amount of middlings as defined above. It is obviously unfair to compare a relatively clean coal

with another having a large amount of heavy impurities whose presence decreases the percentage of middlings for that coal. B. M. Bird[3] eliminates the percentage of material above 2.00 specific gravity, estimated by extrapolation from the specific gravity float curve, page 31, graph 2, and adjusts the remainder proportionately. He next fixes on the specific gravity float curve a point of cut suited to the cleaning of each coal, and calculates the amount of material, adjusted in the above manner, for definite specific gravity intervals. This procedure is likely to give an indefinite point for the percentage of material over 2.00, especially when extrapolated from 1.59 specific gravity, and so was not attempted in the present work. An illustration of the method is given, without this adjustment, for the following coals and points of cut: Coleman, 1.48 s.g., 80% float and 10% ash; Mountain Park, 1.52 s.g., 94% float, 8% ash; Brazeau, 1.56 s.g., 87% float, 10% ash.

Table Showing Specific Gravity Distribution
by Intervals.

Specific Gravity Intervals	Percentage of Material		
	Coleman	Mountain Park	Brazeau
± 0.05	14	1	13
± 0.10	33	9	26
± 0.15	53	18	42
± 0.20	71	32	59

The curves obtained by plotting the percentages of material against the specific gravity intervals are shown on page 39, graph 2. The data indicates that Coleman has the greatest amount of middlings present at any of the specific gravity intervals.

Washability Curves for Reduction of Ash and Loss of Clean Coal.

Two of the chief interests in a washing problem are the relations of the yield to the loss of clean coal in the refuse and to the reduction of ash. This information is not readily available in the washability curves previously described, and hence a new type of washability curve is proposed.

The data required for these derived curves are first obtained from the experimental results in the form of yield-gravity curves as shown on page 31, graph 2. The reduction of ash at any yield is the total ash in the raw coal less the ash in the yield. In the curves for Brazeau coal, divided method, there is 10.0 percentage ash in the yield at 77.3%. The percentage ash in the float is 10% of 77.3, or 7.73 parts per hundred. The reduction of ash is the original % ash of the raw coal, 19.33%, less the 7.73 parts per hundred, or 11.60. The reduction of ash may then be expressed as a percentage of 19.33, as 60.0%. Other reductions in ash may then be computed for various yields and a curve plotted.

The percentage loss of combustible matter is found in a similar manner, assuming that the total amount of combustible matter in the raw coal is 100-19.33, or 80.67%. The loss of combustible matter at any yield is the total combustible matter in the raw coal less the total combustible matter recovered at that yield. In 77.3 parts of yield, the combustible matter is 77.3 less the 10% ash it contains, or 69.57 parts. The loss of combustible matter is therefore 80.67-69.57 or 11.10 parts. This corresponds to 13.8% of the original combustible matter. Other percentages are similarly calculated.

The following table shows the % reduction of ash and % loss of combustible matter for the divided sample procedure on Brazeau coal, derived

from graph 1 page 31.

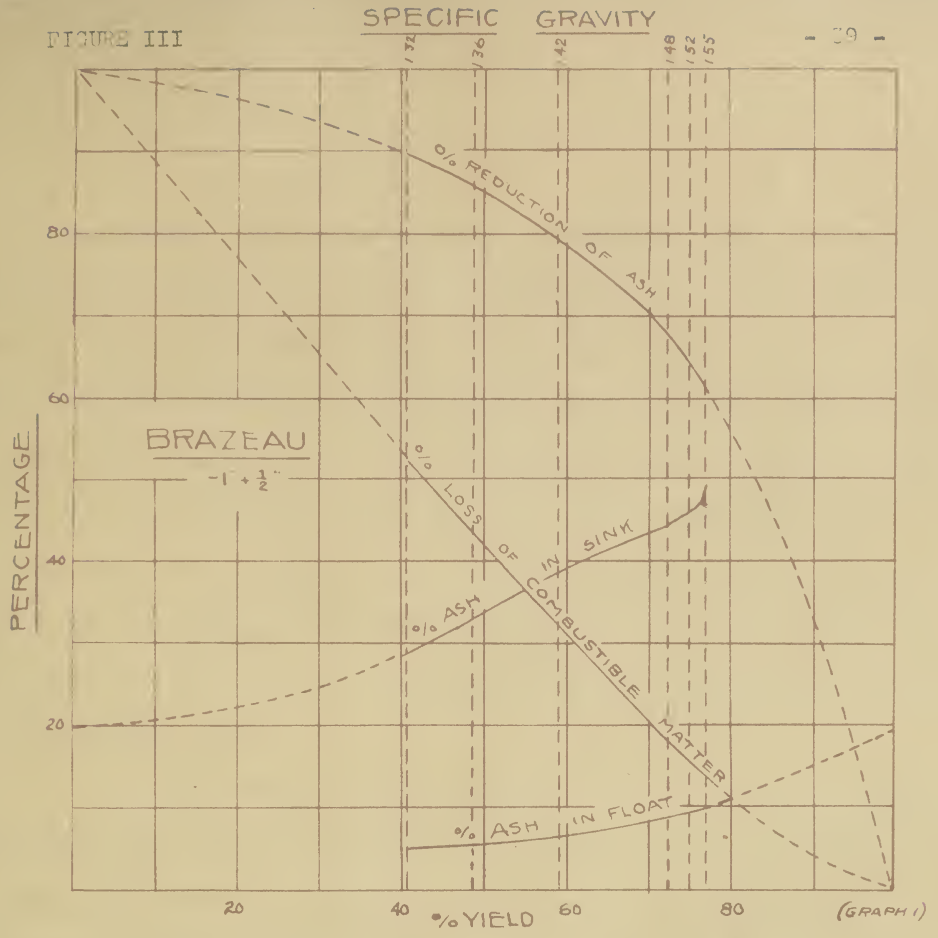
Yield %	Ash %	Ash in Float (parts per 100)	Reduction of ash (parts per 100)	% Reduction of Ash	Loss of clean coal (parts per 100)	% Loss of clean coal
100.0	19.33					
77.3	10.0	7.73	11.60	60.0	11.10	13.8
70.0	8.2	5.74	13.59	70.3	16.41	20.2
60.0	7.1	4.26	12.23	78.0	24.93	30.9
50.0	5.6	2.80	16.53	85.5	33.47	41.5
40.0	4.7	1.88	17.45	90.3	42.55	52.7

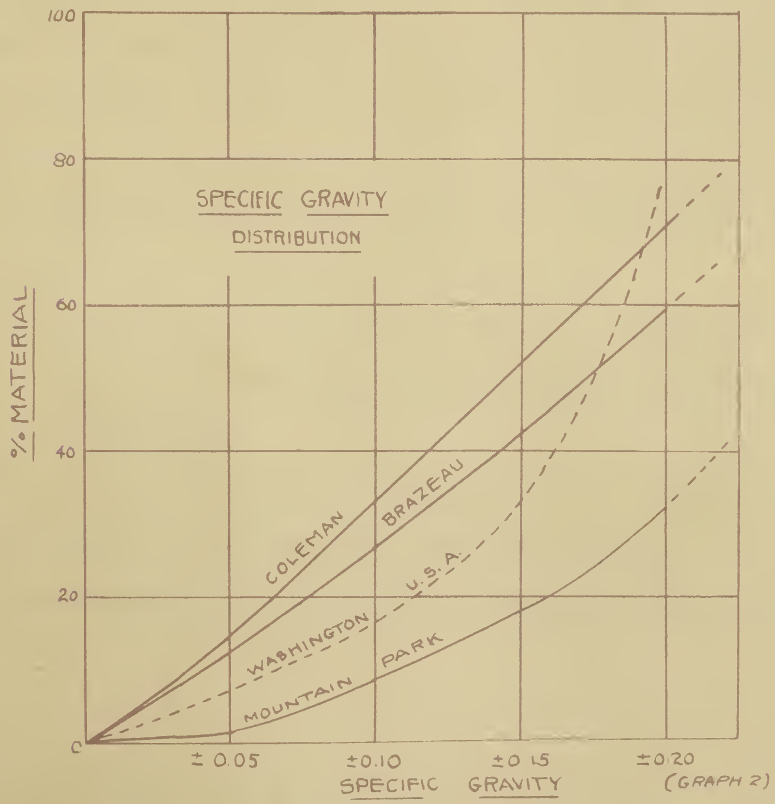
In addition it is noted that a specific gravity of 1.32 corresponds to a yield of 40.8%, 1.355 to 48.3%, 1.42 to 58.3%, 1.48 to 72.7%, 1.51 to 73.3% and 1.55 to 77.3% yield.

In graph 1, page 39, the following points have been plotted against percentage yield: - (1) Percentage reduction of ash, (2) percentage loss of combustible matter, (3) percentage ash in float, (4) percentage ash in sink. Values not included in the above table were taken from the yield-gravity curve, page 31. The percentage yields corresponding to each heavy solution employed are indicated by perpendicular dotted lines.

As the washing is made progressively more drastic, that is with decreasing yield, the curve showing the percentage reduction of ash rises rapidly from zero at 100% yield to 56% reduction at 80% yield. This large initial reduction results from the ease with which the particles over 1.6 specific gravity, and therefore high in ash, are rejected. Below 80% yield the curve rises more slowly, indicating the necessity for rejecting a large amount of material (middlings) in order to effect an appreciable further

FIGURE III


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
PERCENTAGE
80
60
40
20
BRAZEAU
-1" + 1/2"
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD
(GRAPH 1)


100
80
60
40
20
0
% MATERIAL
SPECIFIC GRAVITY
DISTRIBUTION
COLEMAN
BRAZEAU
WASHINGTON U.S.A.
MOUNTAIN PARK
± 0.05
±0.10
±0.15
±0.20
SPECIFIC GRAVITY
(GRAPH 2)

reduction of ash. The curve for loss of combustible matter in the discard shows a more uniform rise, but the percentage loss is still low at 80% yield, that is the refuse contains only a small amount of clean coal. Below 80% yield, the percentage loss increases until it becomes almost proportional to the reduction in yield. The optimum point in the separation of the clean coal from the dirty must depend upon the economic conditions at the cleaning plant, but might be expected to be located somewhere between the points where the reduction of ash curve begins to decrease, and the loss of combustible matter curve commences to increase; that is between 70 and 80% yield in the example given.

The percentage yield lying between two dotted specific gravity lines indicates the amount of material whose specific gravity is between those limits, and hence the position of these lines is a representation of the specific gravity distribution of the coal. Those points on the percentage yield where the gravity lines are close together, tend to show favorable cleaning possibilities, on account of the small amount of material whose specific gravity is approximately the same as those of the points of separation. It may be noted that the gravity lines are closest between 70 and 80% yields, which confirms the conclusions already given.

In coals where it is necessary to effect a reduction of sulphur by cleaning, a similar series of curves could be drawn up for this impurity and included in the same graph.

The new type of graph described above has been used to represent the washability data of the coals tested in this investigation. It is submitted that they give the necessary information in compact and readily accessible form.

CHAPTER VII.

THE WASHABILITY OF SIX ALBERTA COALS.

Screen Analysis.

A screen analysis was made followed by determinations of percentage ash in the various sizes of the raw coal because this gives information with regard to the distribution of the impurities. Thus: -

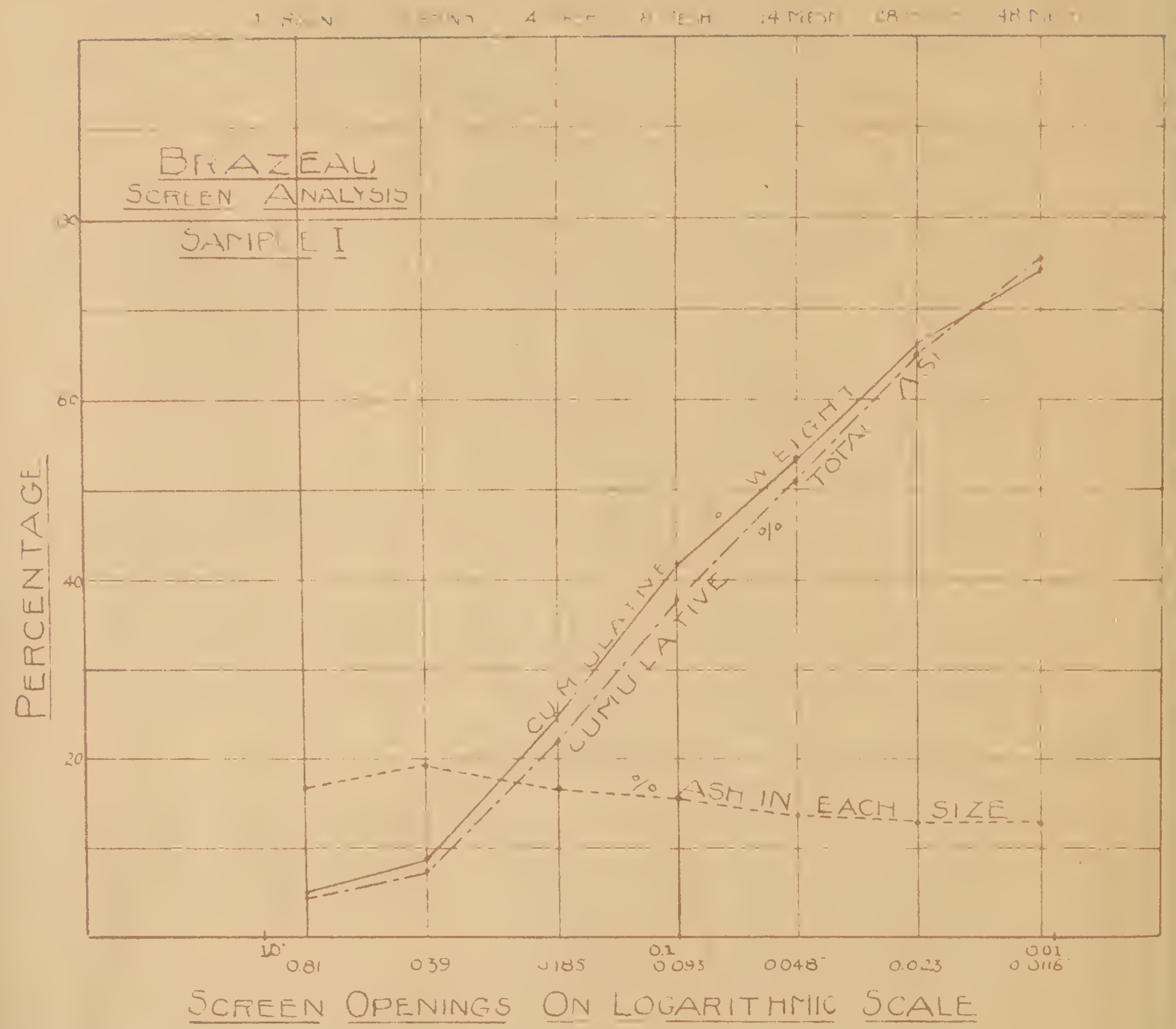
(1) If certain sizes are high in ash, it may be more profitable to use them locally, rather than to clean them. This is often true when there is a large accumulation of friable impurities such as clay in the fines, as it is difficult to clean such fines, and their inclusion uncleaned with the rest of the coal would lower the quality of the marketed product.

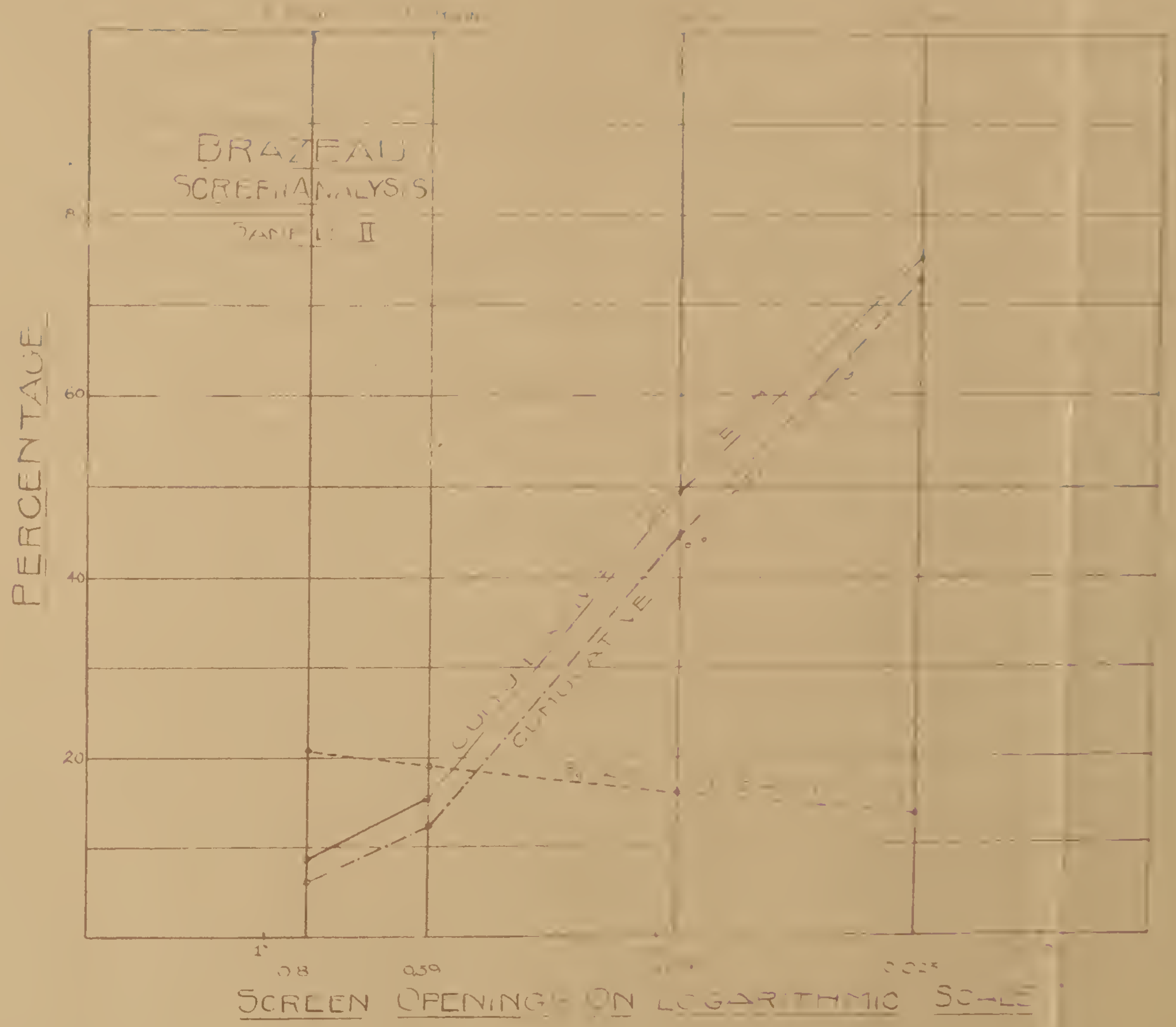
(2) If certain sizes are low in ash, it may be possible to omit cleaning these sizes and yet include them in the marketed product. Vissac[17] states that this practice is followed in the Greenhill plant with the fines under 1/8 inch mesh.

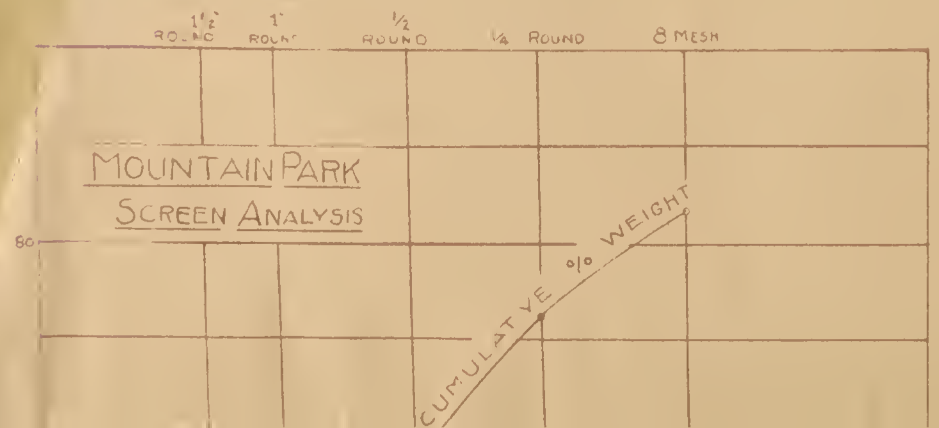
(3) When there is a greater percentage ash in the fines than in the other sizes, it indicates that the impurities are more friable than the coal. According to Chapman and Mott[4], many coals of this nature may be improved by crushing prior to washing.

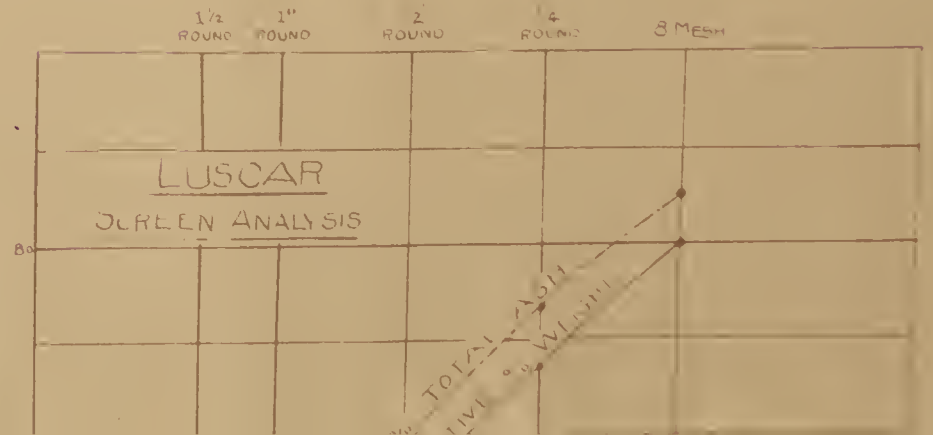
The screening was made on a small Marcus shaker screen, the larger sizes with perforated screens and the smaller sizes below ½ inch diameter with standard wire mesh. A correlation of the two types of screens was made by assuming that the relative amounts passed by square holes and round holes respectively, were proportional to the area of the openings. (Taggart[15]).

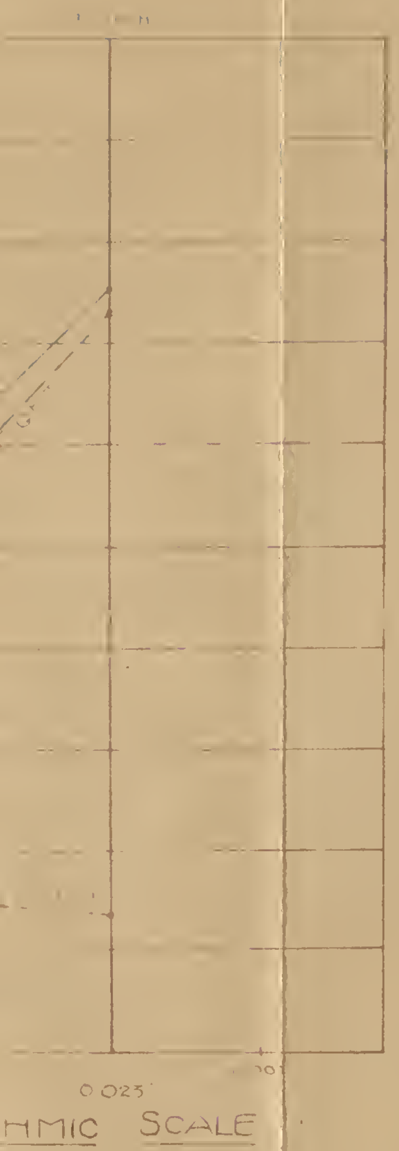
On page 42 are shown the screen analysis curves of the six coals, obtained by plotting the cumulative weights and percentage ash for each

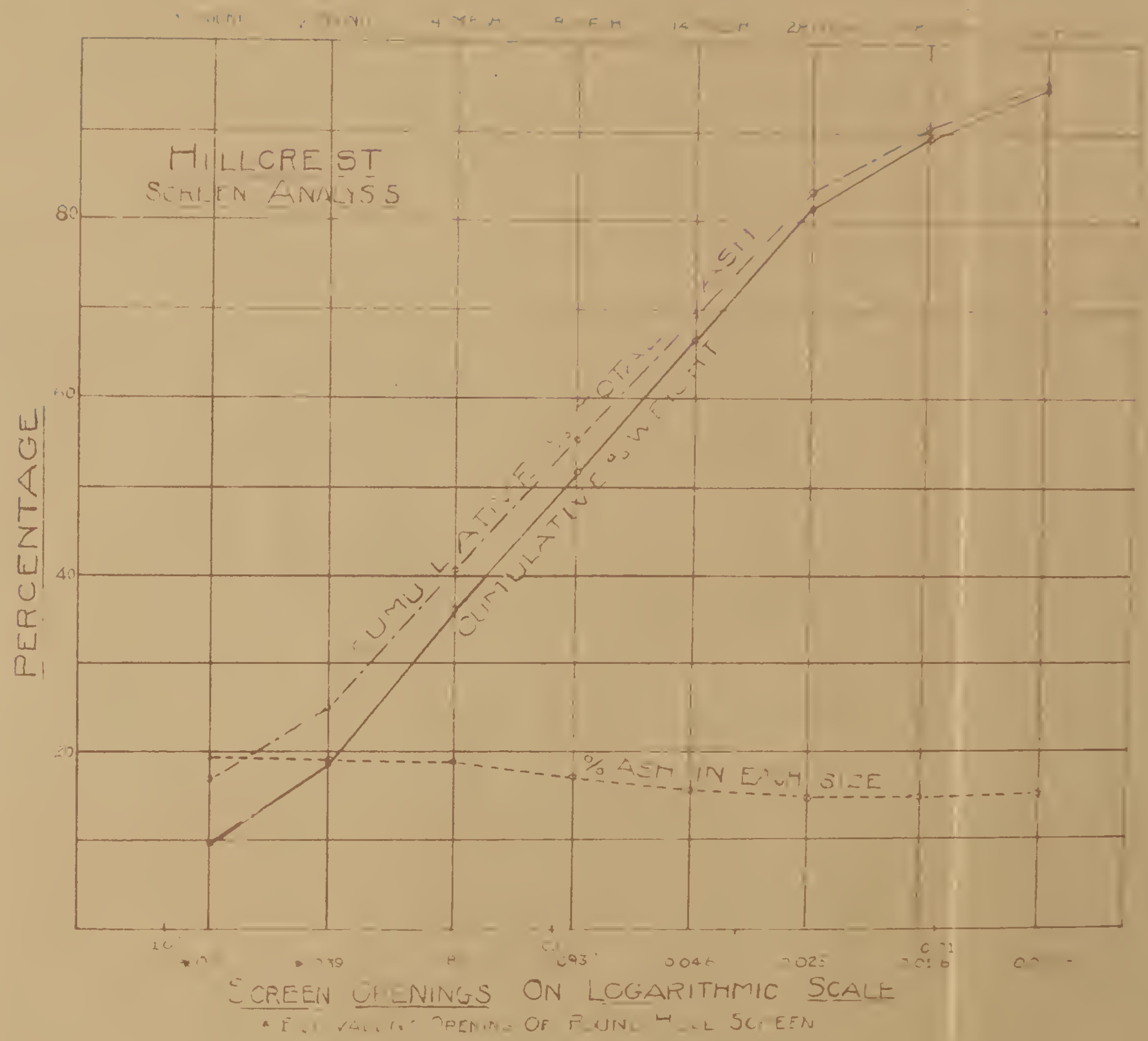

BRAZEAU
SCREEN ANALYSIS
SAMPLE I
14 MESH
28
48
80
60
40
20
PERCENTAGE
CUMULATIVE % WEIGHT
CUMULATIVE % TOTAL ASH
% ASH IN EACH SIZE
1.0"
0.81
0.39
0.185
0.1
0.093
0.048
0.023
0.01
0.0116
SCREEN OPENINGS ON LOGARITHMIC SCALE

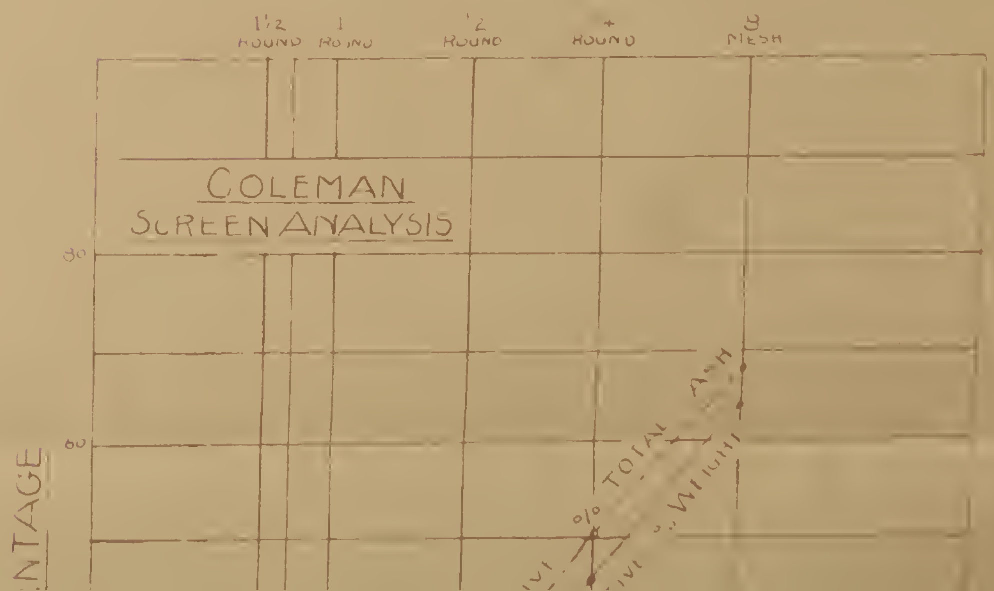

BRAZEAU
SCREEN ANALYSIS
SAMPLE II
80
60
40
20
PERCENTAGE
CUMULATIVE
CUMULATIVE
1"
0.8
0.39
SCREEN OPENINGS ON LOGARITHMIC SCALE

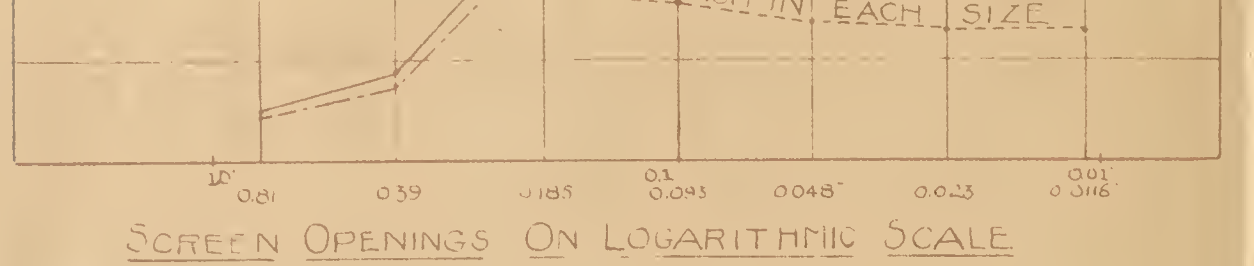

1½ ROUND
1" ROUND
½ ROUND
¼ ROUND
8 MESH
MOUNTAIN PARK
SCREEN ANALYSIS
80
CUMULATIVE % WEIGHT

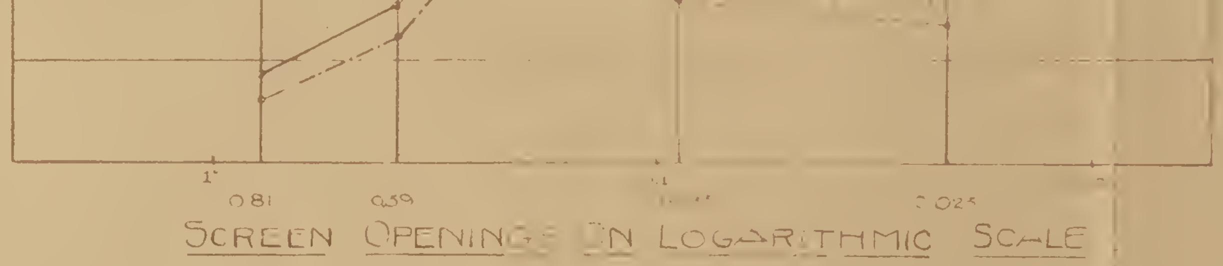

1½ ROUND
1" ROUND
½ ROUND
¼ ROUND
8 MESH
LUSCAR
SCREEN ANALYSIS
80
TOTAL ASH
% WEIGHT

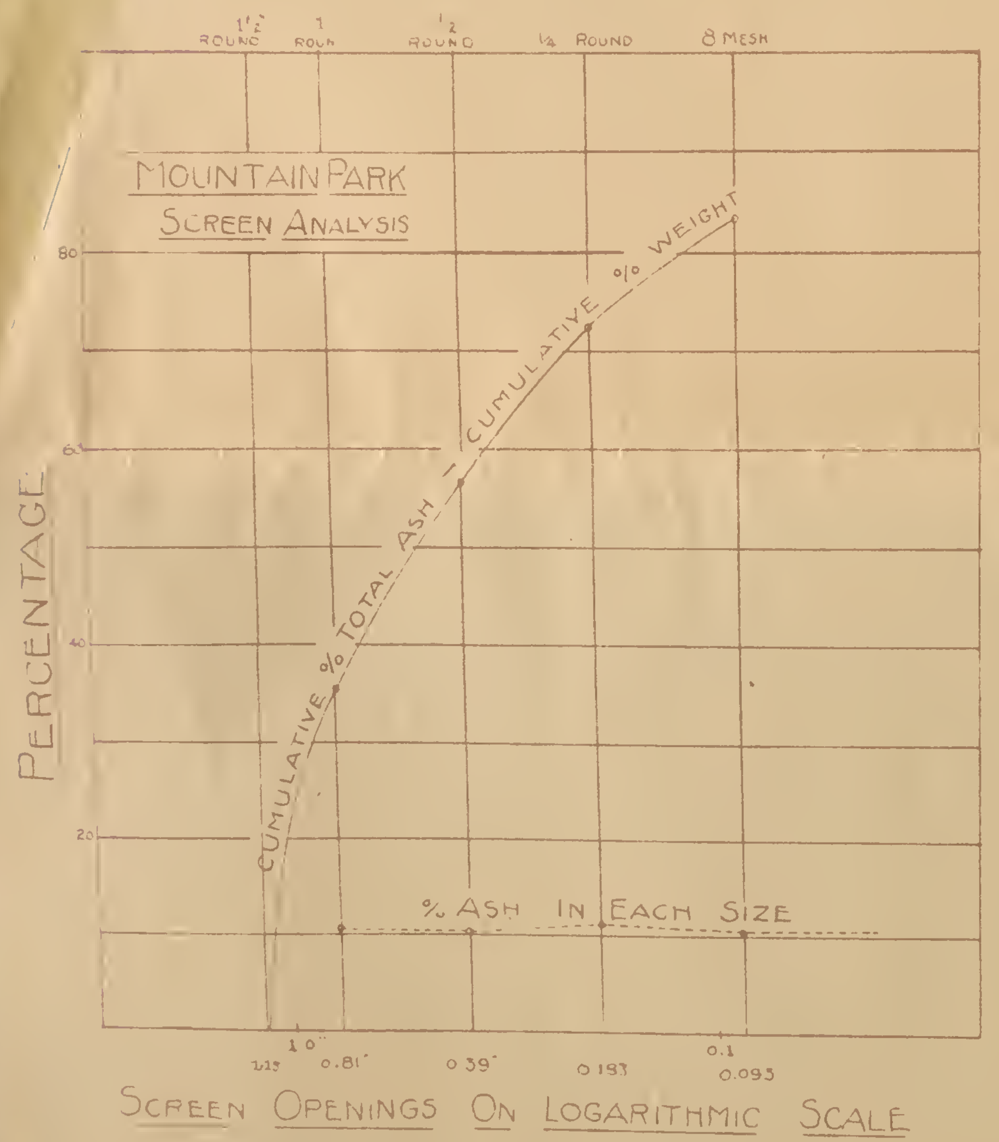

0.025
HMIC SCALE

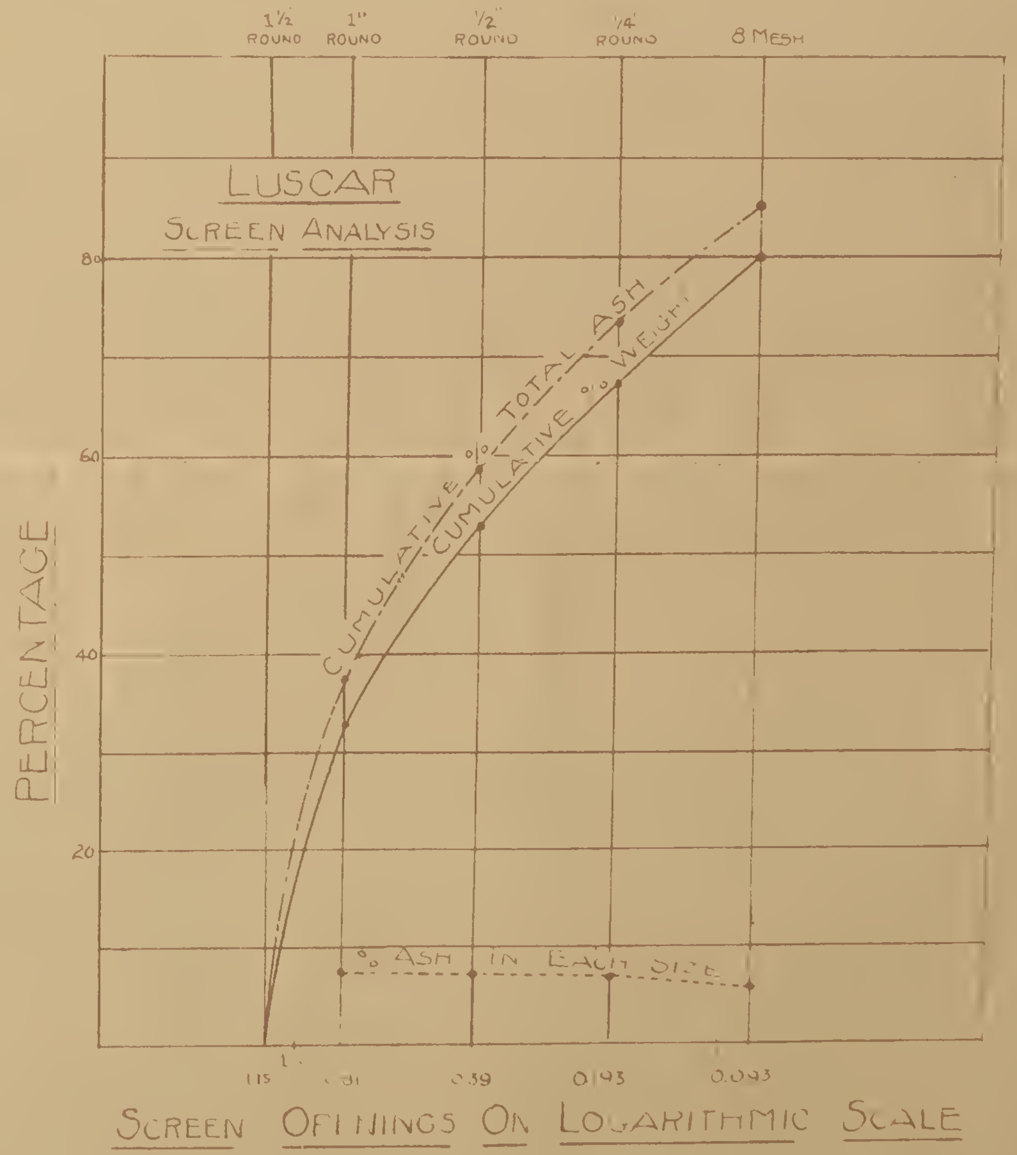

HILLCREST
SCREEN ANALYSIS
80
60
40
20
PERCENTAGE
CUMULATIVE % TOTAL ASH
CUMULATIVE % WEIGHT
% ASH IN EACH SIZE
.039
.093
0.046
.025
SCREEN OPENINGS ON LOGARITHMIC SCALE
OPENING OF ROUND HOLE SCREEN

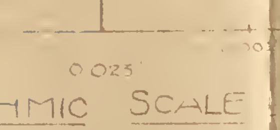

1½ ROUND
1 ROUND
½ ROUND
¼ ROUND
8 MESH
COLEMAN
SCREEN ANALYSIS
80
60
NTAGE
% TOTAL ASH
WEIGHT

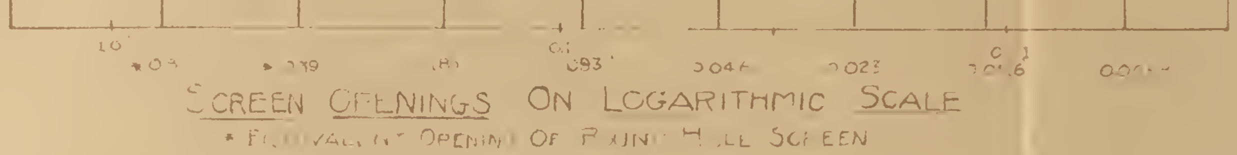

IN EACH SIZE
1.0"
0.81
0.39
0.185
0.1
0.093
0.048"
0.023
0.01"
0.0116"
SCREEN OPENINGS ON LOGARITHMIC SCALE


1"
0.81
0.39
0.1
0.023
SCREEN OPENINGS ON LOGARITHMIC SCALE

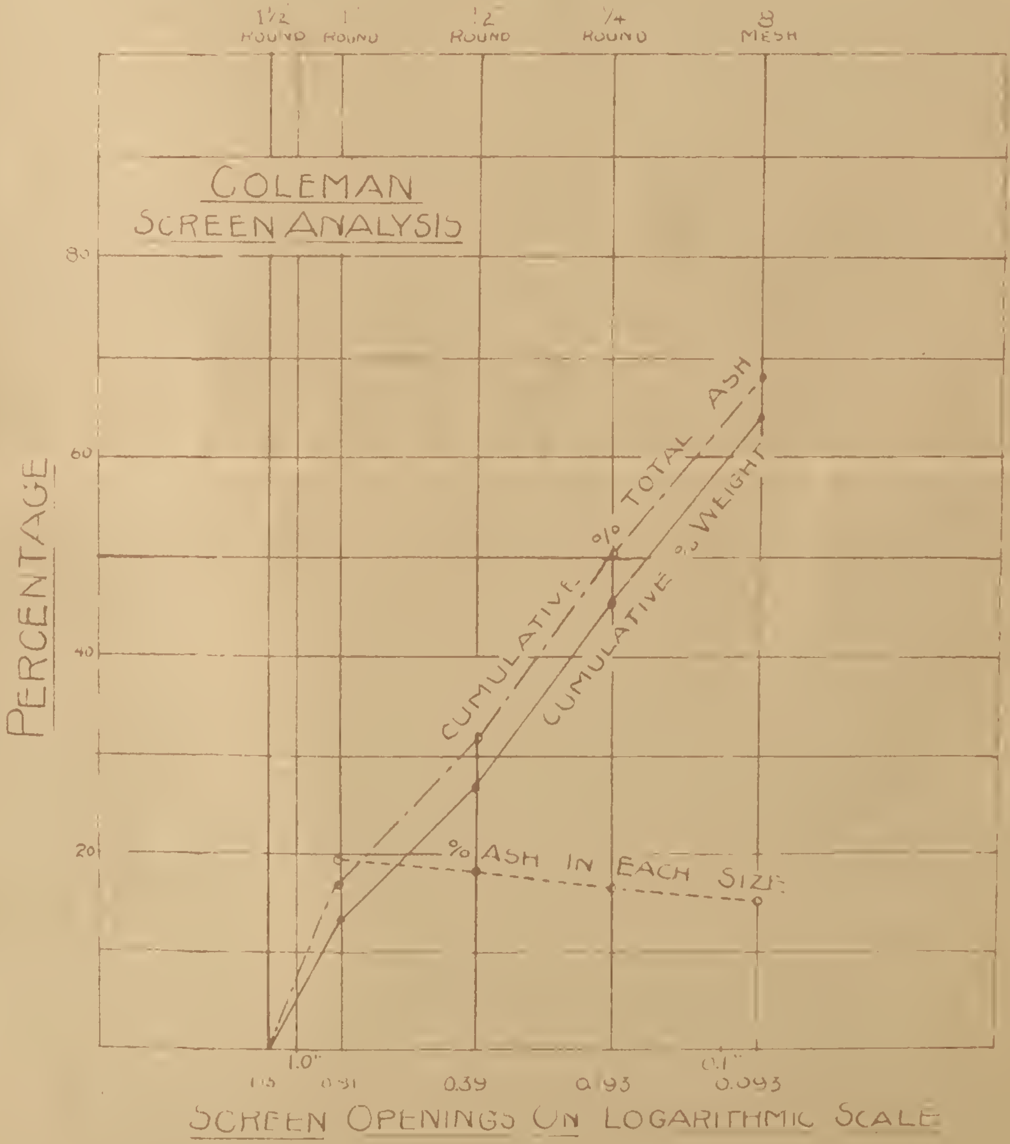

1½" ROUND
1" ROUND
½" ROUND
¼ ROUND
8 MESH
MOUNTAIN PARK
SCREEN ANALYSIS
CUMULATIVE % WEIGHT
CUMULATIVE % TOTAL ASH
% ASH IN EACH SIZE
PERCENTAGE
80
60
40
20
1.0"
1.15
0.81"
0.39"
0.193
0.1
0.093
SCREEN OPENINGS ON LOGARITHMIC SCALE


1½ ROUND
1" ROUND
½" ROUND
¼" ROUND
8 MESH
LUSCAR
SCREEN ANALYSIS
CUMULATIVE % TOTAL ASH
CUMULATIVE % WEIGHT
% ASH IN EACH SIZE
PERCENTAGE
80
60
40
20
1.15
1"
0.81
0.39
0.193
0.093
SCREEN OPENINGS ON LOGARITHMIC SCALE


0.025
...HMIC SCALE


1.0
0.1
0.093
0.046
0.023
SCREEN OPENINGS ON LOGARITHMIC SCALE
* EQUIVALENT OPENING OF ROUND HOLE SCREEN

...ALE


COLEMAN
SCREEN ANALYSIS
1½ ROUND
1" ROUND
½" ROUND
¼ ROUND
8 MESH
PERCENTAGE
80
60
40
20
CUMULATIVE % TOTAL ASH
CUMULATIVE % WEIGHT
% ASH IN EACH SIZE
1.0"
0.1"
1.5
0.91
0.39
0.193
0.093
SCREEN OPENINGS ON LOGARITHMIC SCALE

Sample and Source	Sizes Tested	Apparatus	Method
1. Hillcrest. Part of 1000 lb. sample from Hillcrest Collieries, on March 6, 1929	-$\frac{1}{2}$" + $\frac{1}{4}$"	Beaker	D.S.
	-4 + 8 mesh	Centrifuge	"
	-8 + 14 "	"	"
	-28 +48 "	"	"
	-100 "	"	"
2. Brazeau #1. Part of 1800 lb. sample from Brazeau Coal Co. Nordegg, on June 5, 1929	+1"	K & T App.	D. S.
	-1 + $\frac{1}{2}$"	"	"
	-$\frac{1}{2}$ + $\frac{1}{4}$"	"	"
	-$\frac{1}{4}$"+ 8 mesh	"	"
	-8 + 14 "	"	"
	-14 + 28 "	"	"
	-28 + 48 "	Centrifuge	"
	-48 mesh	"	"
3. Coalspur. Part of 1000 lb. sample received from Coal Valley during 1927	-1 + $\frac{1}{4}$"	K & T	D. S.
4. Brazeau #2. 200 lb. sample received from Brazeau Coal Co. Nordegg, on June 5, 1929	- 1$\frac{1}{2}$ + 1	K & T	U. S.
	-1 + $\frac{1}{2}$	"	"
	-$\frac{1}{2}$" + 8 mesh	"	"
	-8 + 28 "	"	"
	- 28 "	Centrifuge	D. S.
5. Mountain Park. 110 lb. sample received from Mountain Park Colieries, on November 1, 1929	-1$\frac{1}{2}$ + 1	K & T	U. S.
	-1 + $\frac{1}{2}$	"	"
	-$\frac{1}{2}$ + $\frac{1}{4}$	"	"
	-$\frac{1}{4}$ + 1/8	"	"
	- 1/8	Centrifuge	D. S.
6. Luscar. 65 lb. sample received from Luscar Collieries, Ltd. Luscar, on November 1, 1929	-1$\frac{1}{2}$ + 1	K & T	U. S.
	-1 + $\frac{1}{2}$	"	"
	-$\frac{1}{2}$ + 1/4	"	"
	-$\frac{1}{4}$ + 1/8	"	"
	- 1/8	Centrifuge	D. S.
7. Coleman. 100 lb. sample received from International Coal and Coke Co., Coleman, on November 15, 1929	-1$\frac{1}{2}$ + 1	K & T	U. S.
	-1 + $\frac{1}{2}$	"	"
	-$\frac{1}{2}$ + $\frac{1}{4}$	"	"
	-$\frac{1}{4}$ + 1/8	"	"
	- 1/8	Centrifuge	D. S.

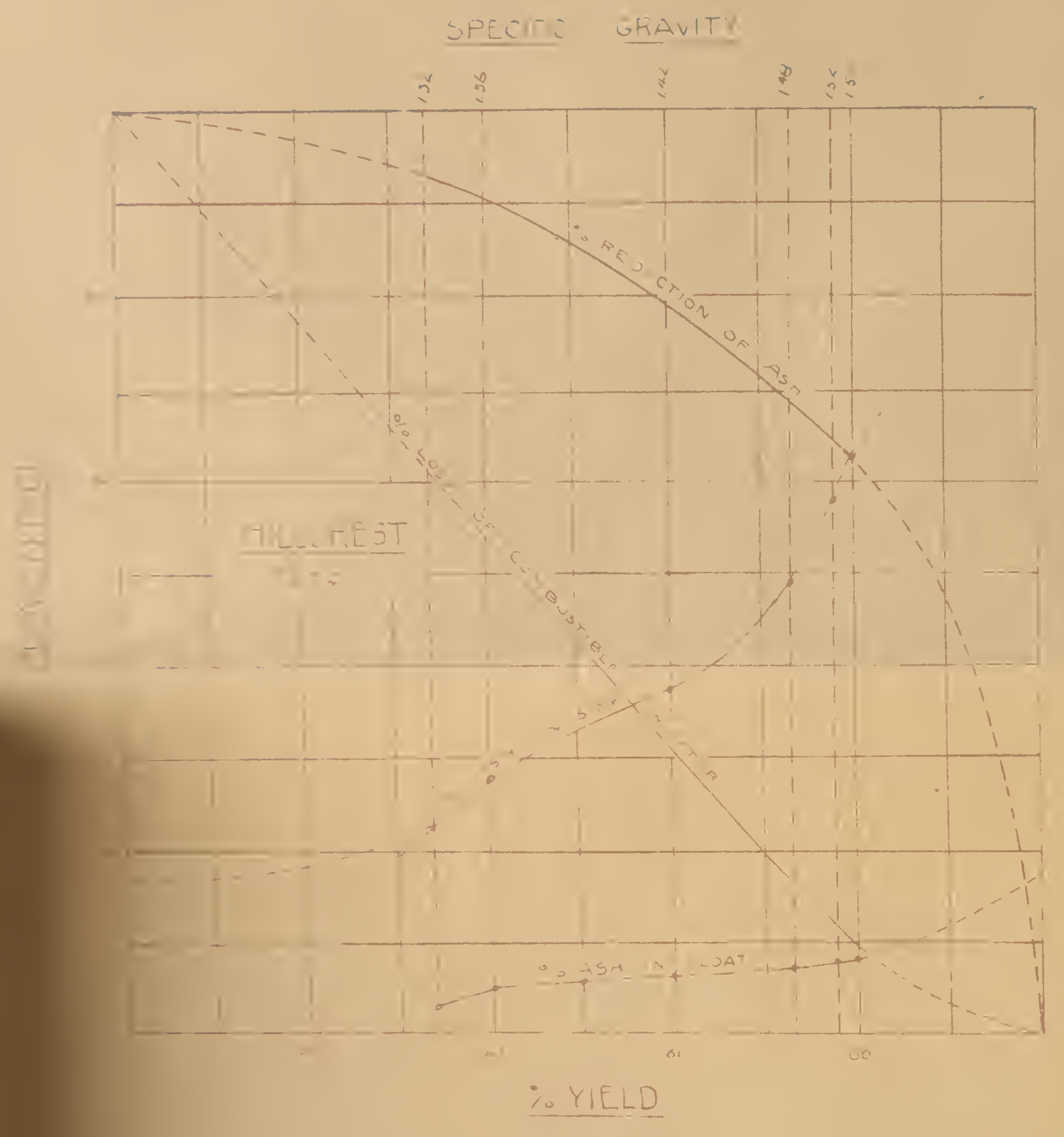
size against the screen opening on logarithmic scale. They show that the larger sizes of most of these coals are slightly dirtier than the fines. This indicates that the dirt is less friable than the clean coal. When the various sizes contain about the same amount of ash, one may infer that the impurities are present either in disseminated condition or that the friabilities of the coal and its localized impurities are similar.

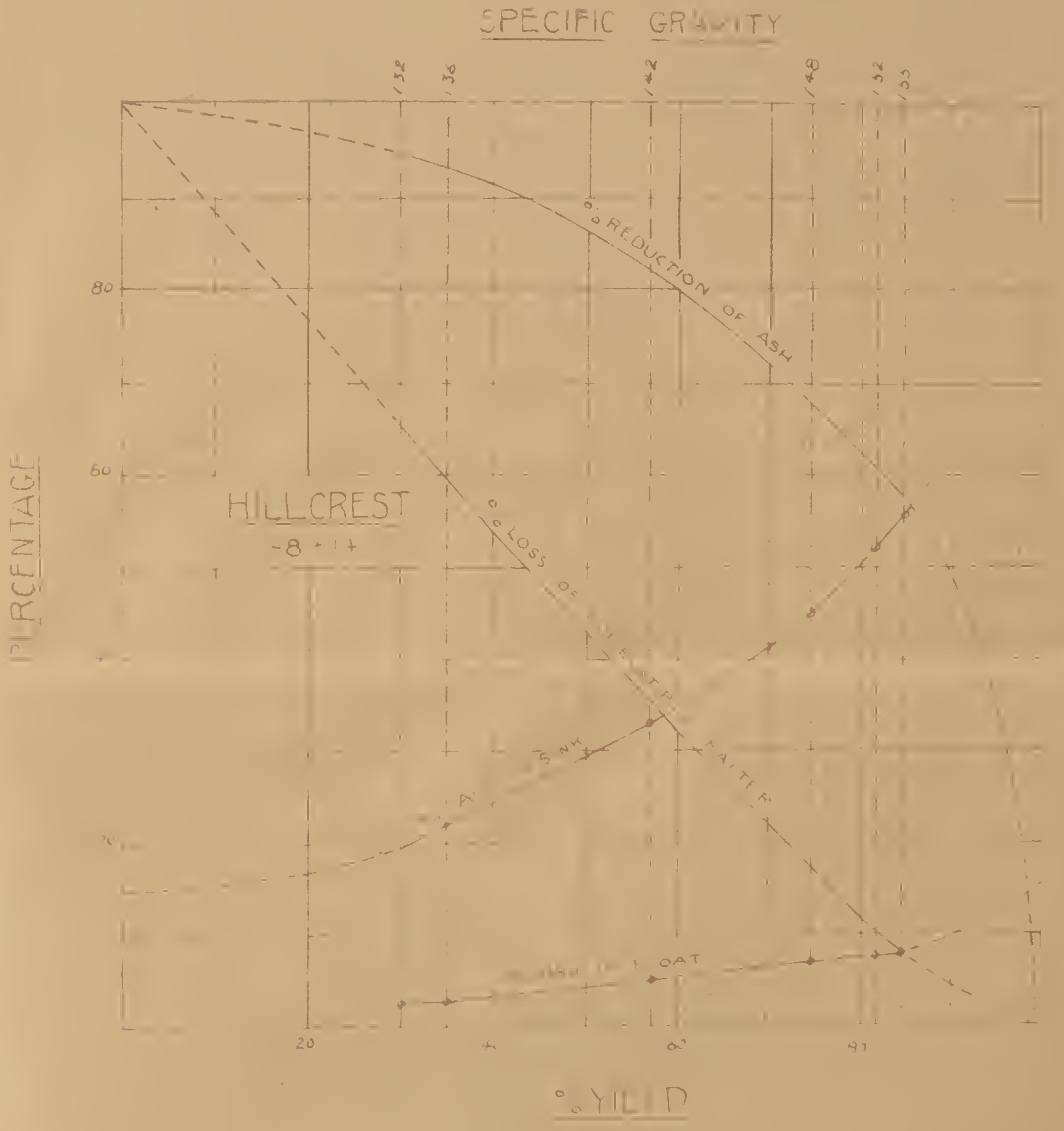
Float and Sink Tests.

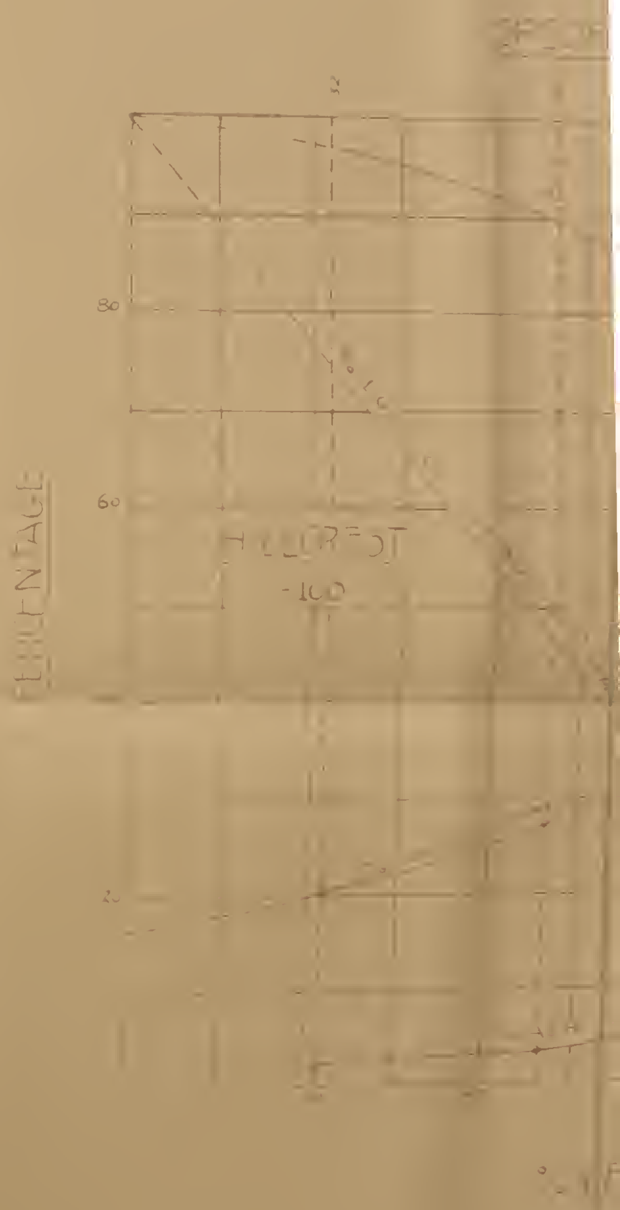
The float and sink tests were made by the divided method of procedure where possible. The various samples tested, amounts, sizes, and methods employed, etc. are tabulated on page 43. Notes and conclusions with respect to the six coals are given in the following sections of this chapter. For each coal, curves have been prepared for each size tested, and a composite curve for the run of mine coal calculated on the basis of the percentage of each size found in the screen analysis.

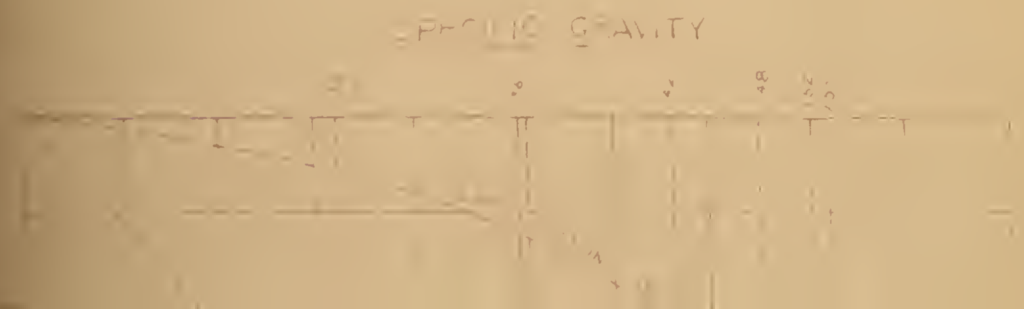
Section 1. Hillcrest. This sample was submitted for briquetting work, but washing tests were carried out as well. The larger particles had a dull appearance and tended toward flatness in shape. A few pieces of shale were visible.

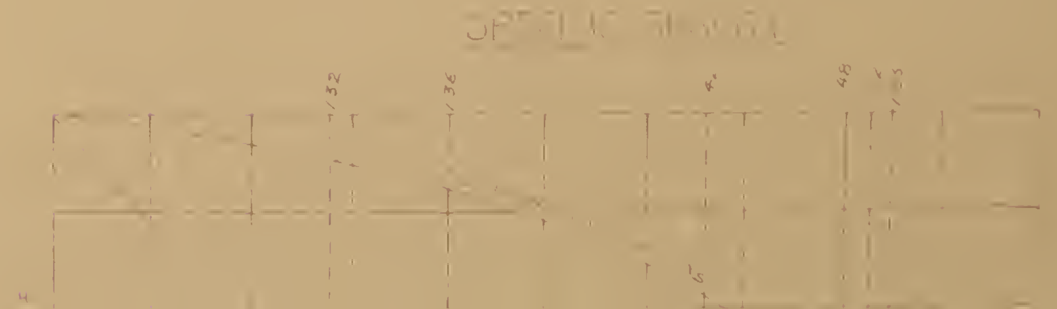
The screen analysis showed a large proportion of slack as over 50% of the sample passed through the 8 mesh screen. The largest size of approximately 1 inch diameter, contained about 20% ash, while the fines were about 15%. The coal was therefore more friable than its impurities, and some ash reduction could be accomplished by screening. The washing of this coal would be considered at the outset to be somewhat difficult on account of the friable nature of the coal and the large amount of fines.

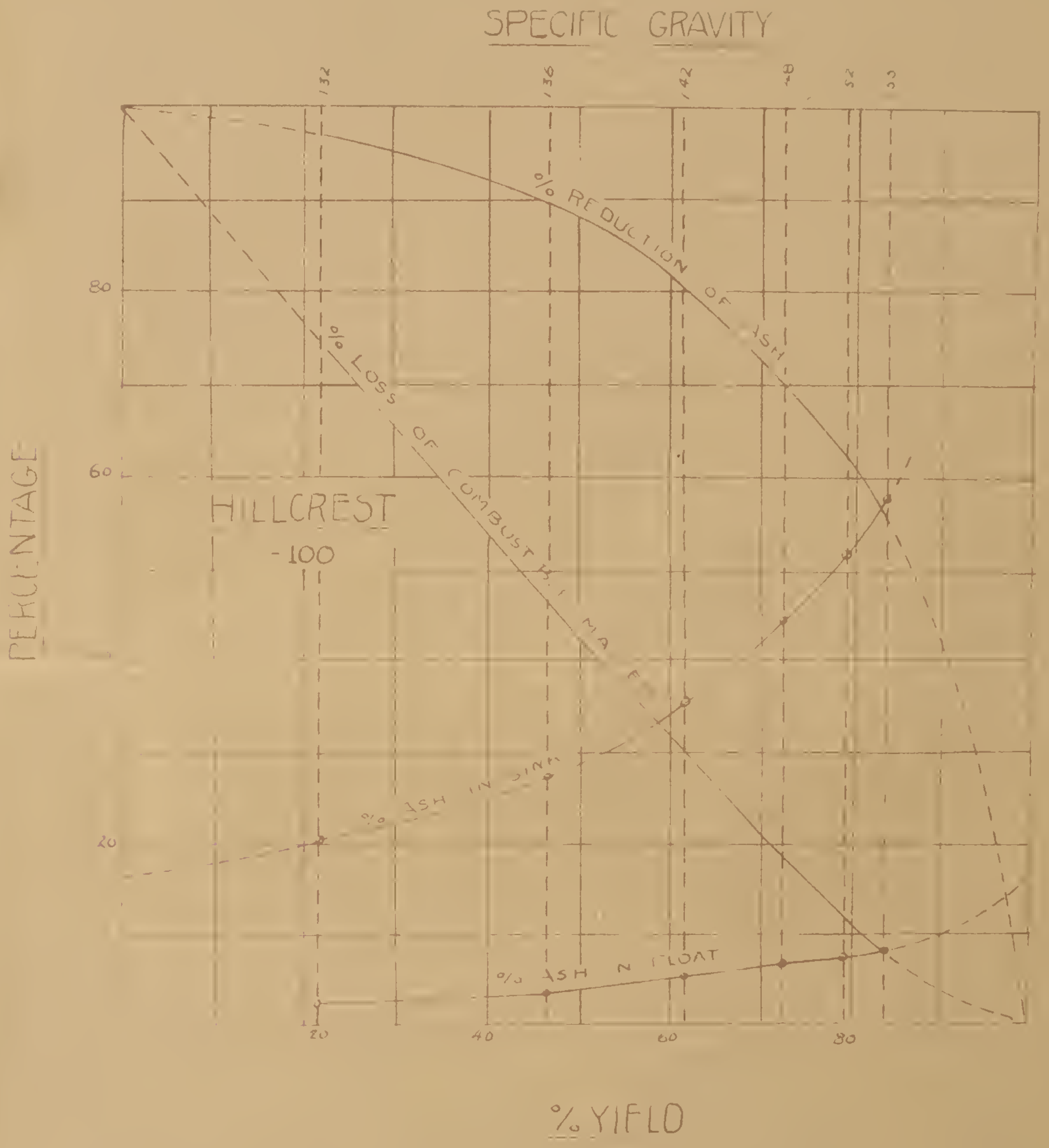

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
HILLCREST
60
% YIELD

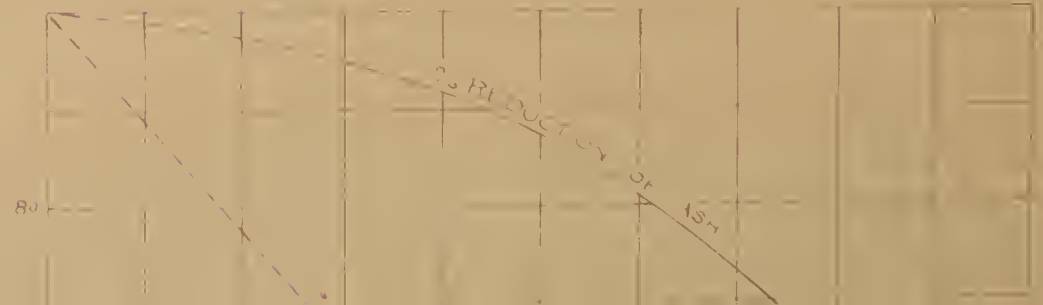

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80
60
PERCENTAGE
HILLCREST
-8+14
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
80
% YIELD

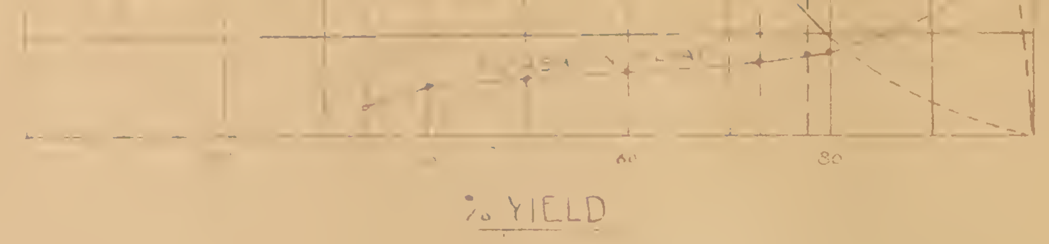

80
60
PERCENTAGE
HILLCREST
-100


SPECIFIC GRAVITY

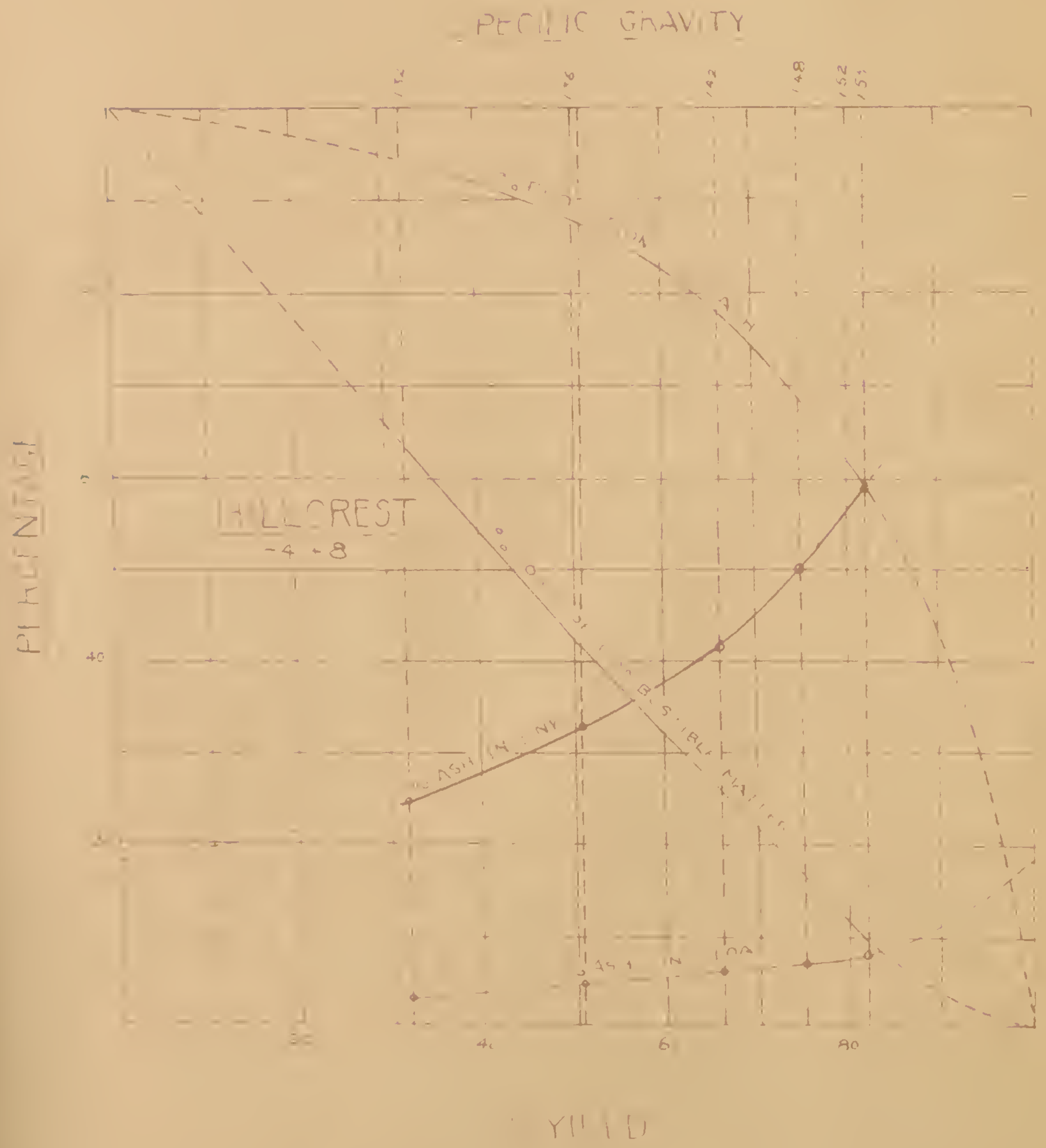

SPECIFIC GRAVITY
1.32
1.36


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
PERCENTAGE
80
60
20
HILLCREST
-100
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

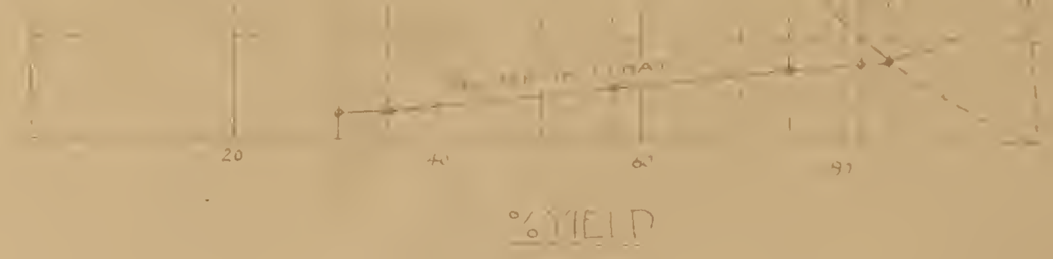

80
% REDUCTION OF ASH



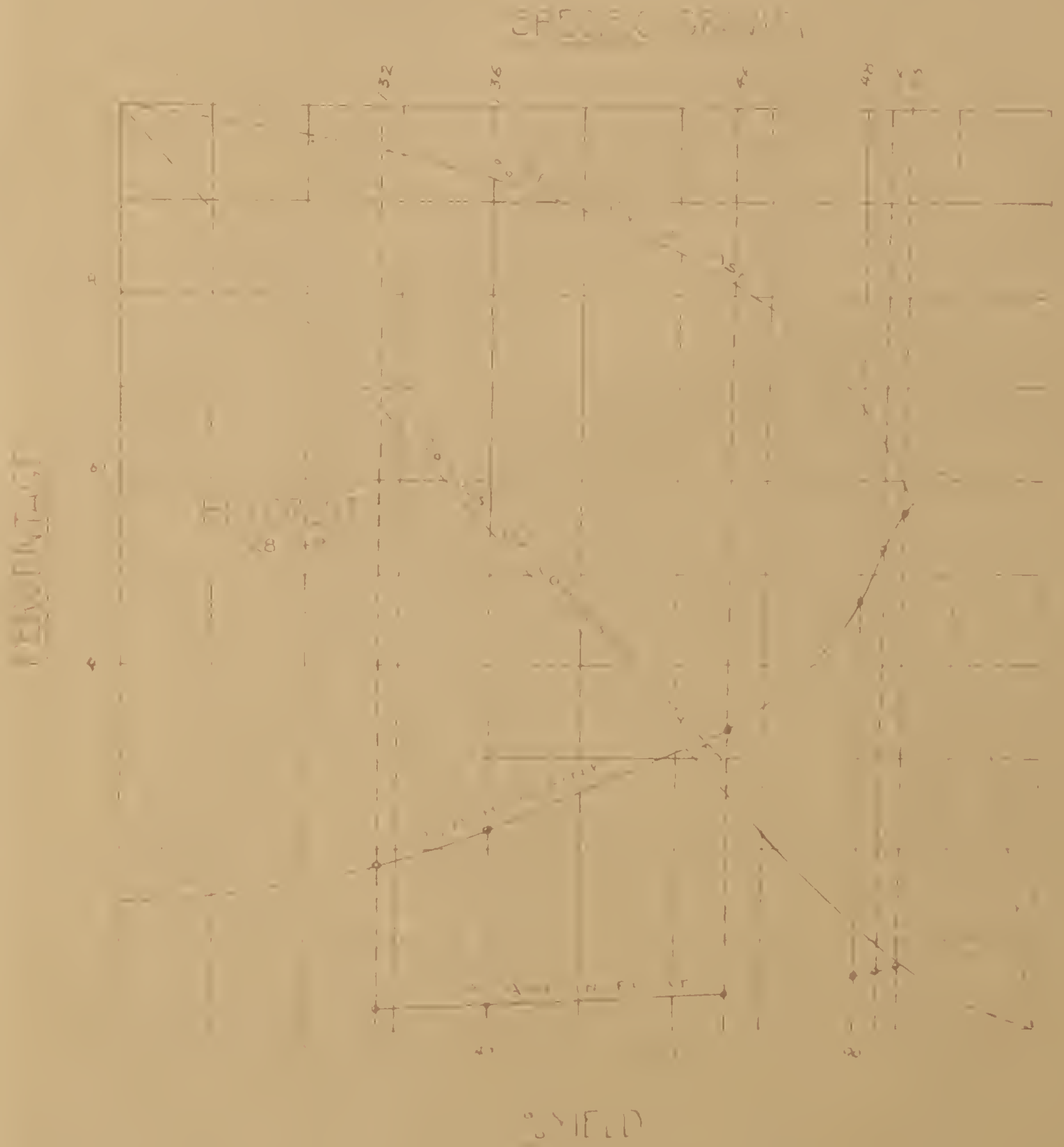
60
80
% YIELD



SPECIFIC GRAVITY
.32
.36
.42
.48
.52
.54
PERCENTAGE
HILLCREST
-4 +8
40
20
ASH IN FLOAT
40
60
80
% YIELD

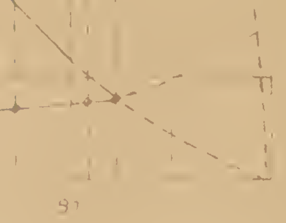


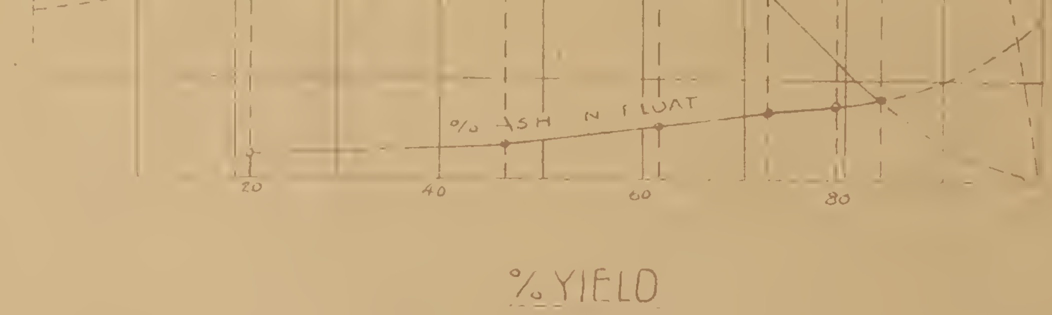
20
40
60
80
% YIELD

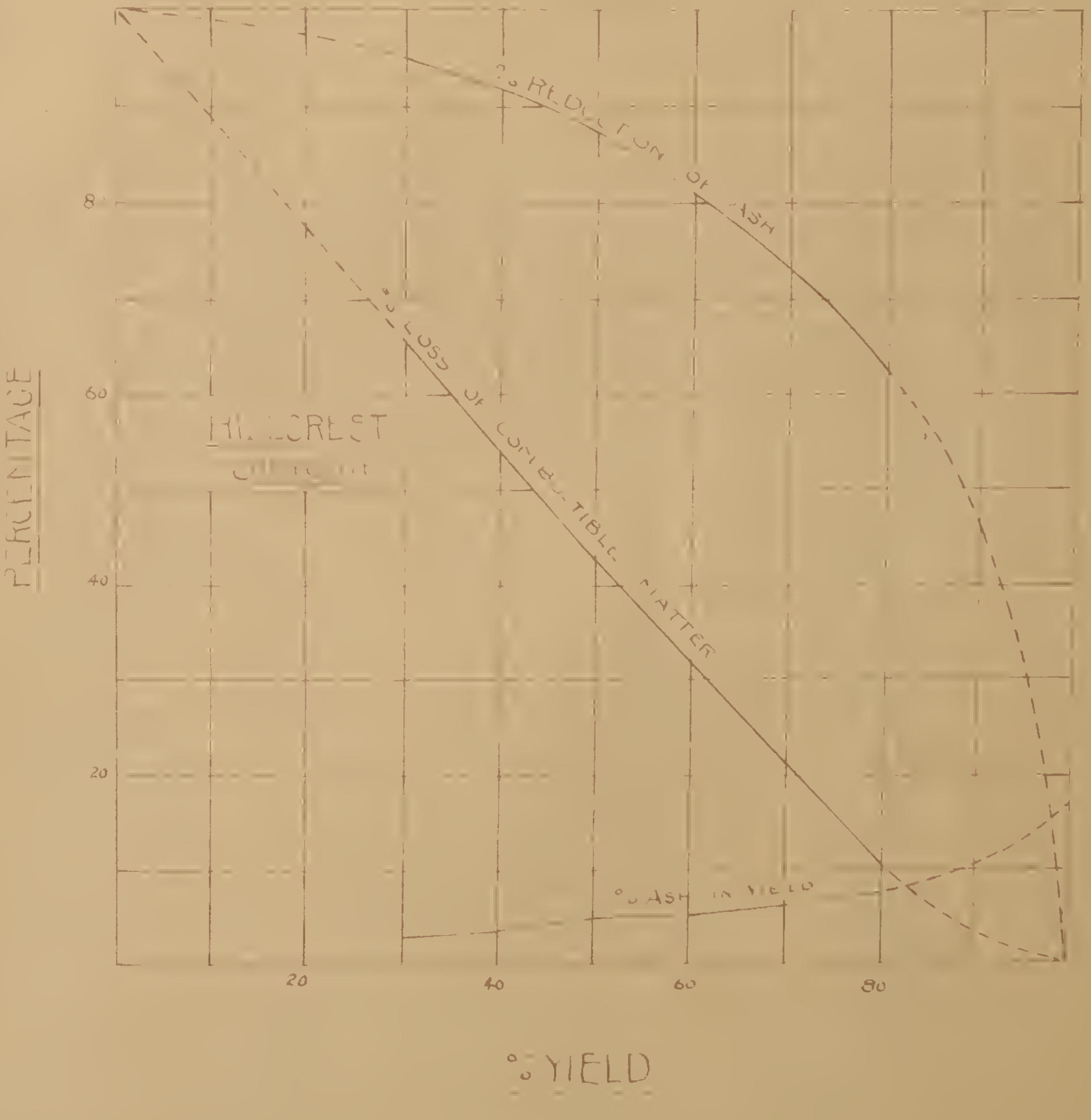


SPECIFIC GRAVITY
.32
.36
PERCENTAGE
% YIELD

PERCENTAGE




% ASH IN FLOAT
20
40
60
80
% YIELD

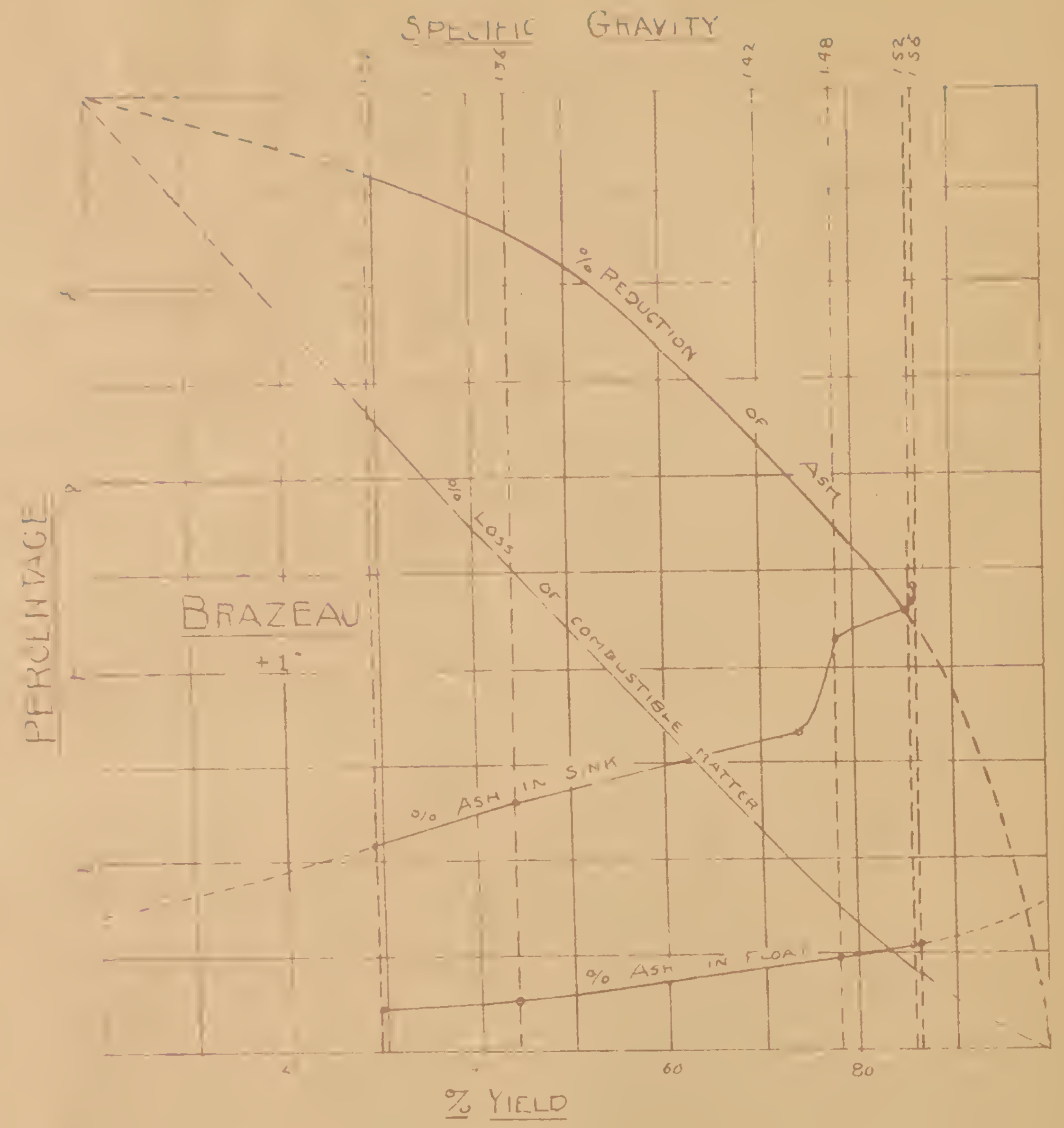

% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN YIELD
HILLCREST
PERCENTAGE
80
60
40
20
20
40
60
80
% YIELD

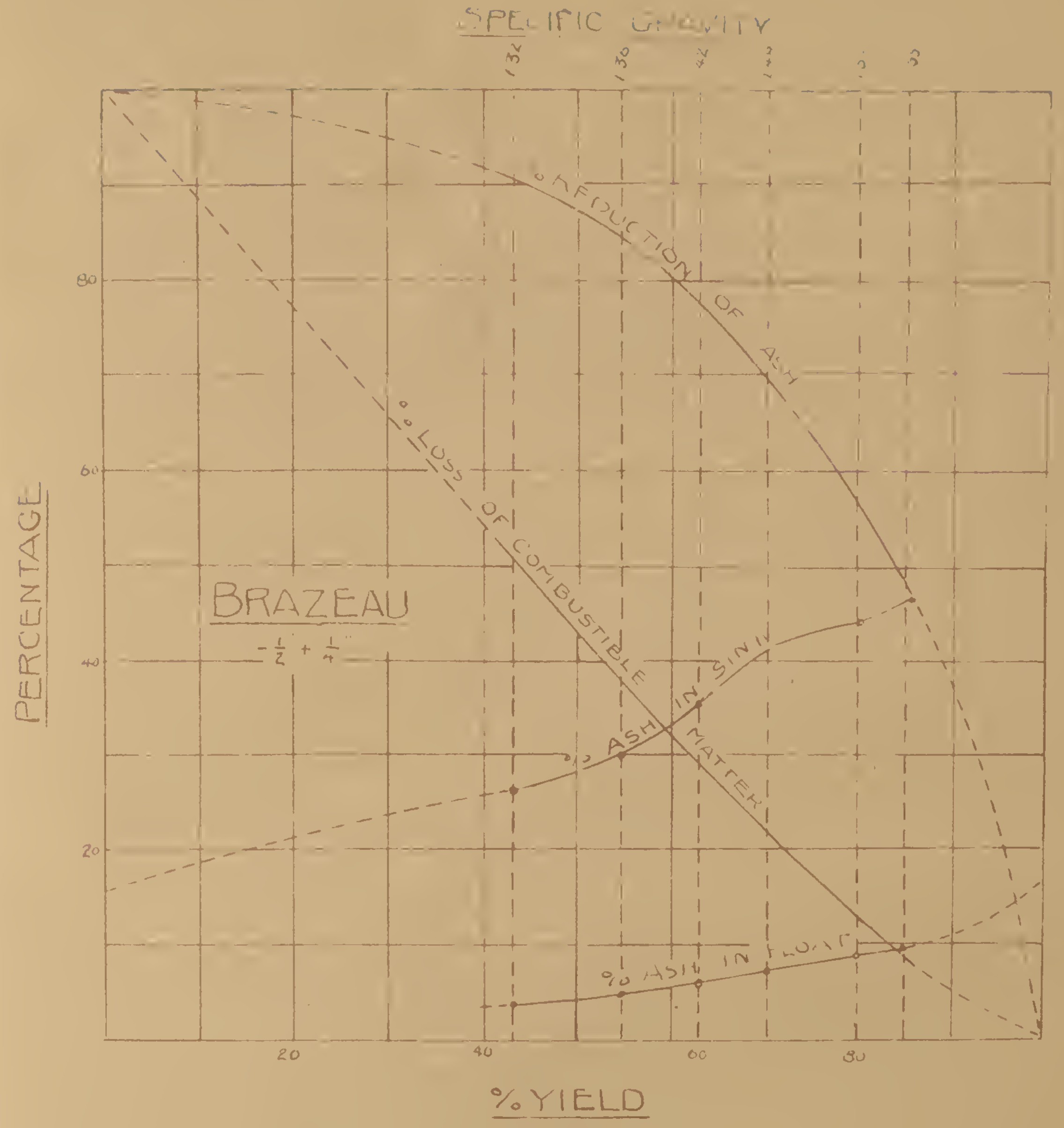
Only five of the sizes were subjected to washability tests. These sizes ranged from smaller than $\frac{1}{2}$ inch to through 100 mesh. The float and sink tests were carried out by the divided sample method, using beaker and centrifuge procedures. The results of these tests are expressed graphically on page 45 for each of the sizes and for a composite sample (run of mine). The average specific gravity distribution as estimated from the various curves indicates that 60 to 65% of the material is lighter than 1.42 specific gravity, about 20% is between 1.42 and 1.55 (middlings) and the remainder heavier than 1.55. Compared with the other coals in this series of tests, the coal has a wide gravity distribution and is therefore not easily separated. The operation of a washery might be adjusted to give between 80 and 90% recovery with from 7 to 10% of ash in the cleaned coal.

The reduction of ash curves show that a considerable reduction of ash may be expected. At 80% recovery, the cleaned coal contains about 7% ash, and the refuse about 55%. The loss of clean coal at this yield is about 10% and reduction of ash about 60%.

Most of the washability tests for this coal were made on small sizes and for such coal the data indicates that good reduction of ash is possible. The practical cleaning of this coal would be rendered somewhat difficult on account of the large amount of fines. The possibility of by-passing the fines and adding them uncleaned to the cleaned coal could be considered only if a product of about 12% ash is permissible.

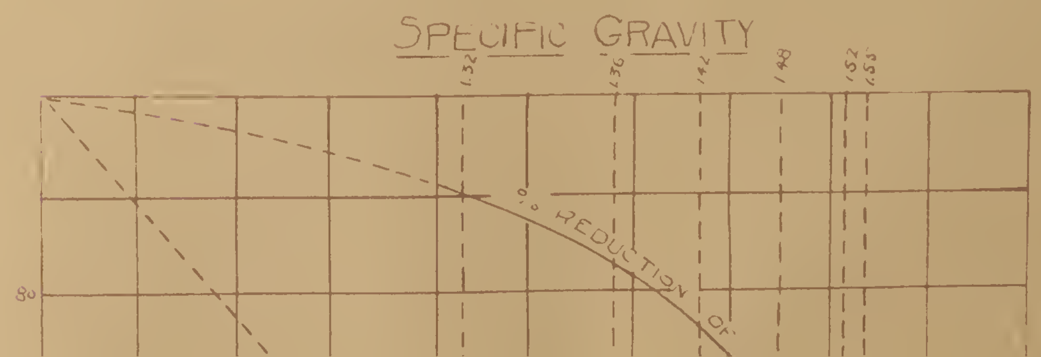
Section II. Brazeau #1. A very complete series of washing tests were carried out on this sample submitted for briquetting work. Some impurities were visible as streaks of shale of carbonaceous material in the lumps of larger coal, otherwise the sample was apparently of uniform composition.

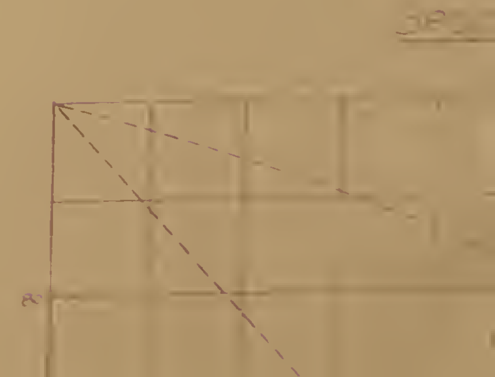

SPECIFIC GRAVITY
1.36
1.42
1.48
1.52
1.58
PERCENTAGE
BRAZEAU
+1"
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
60
80
% YIELD

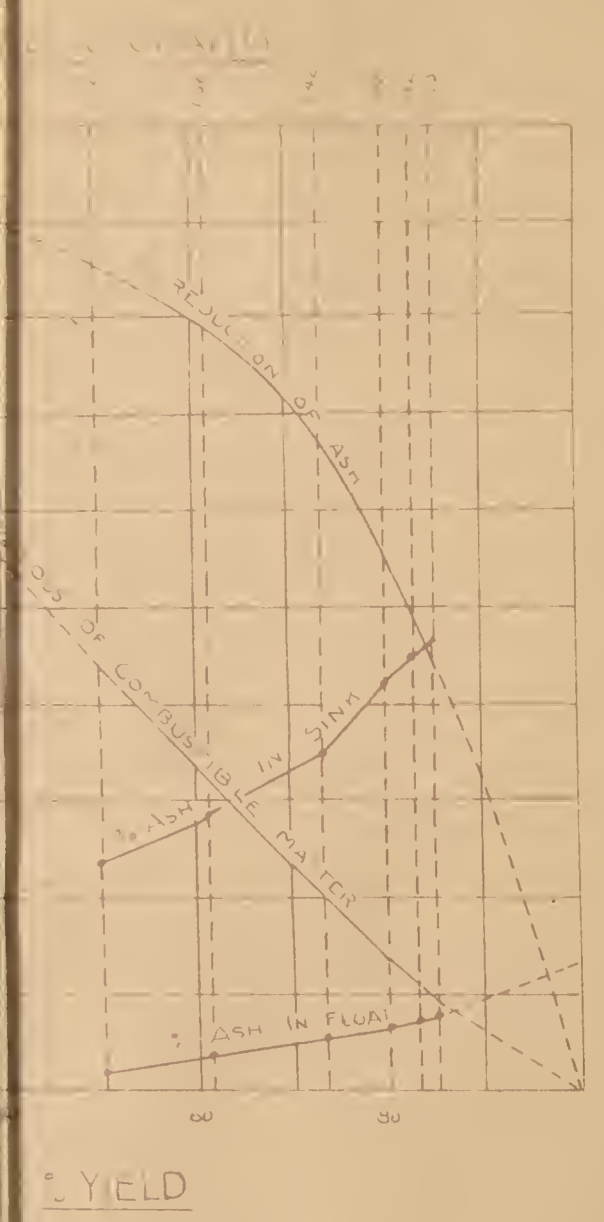

SPECIFIC GRAVITY
1.32
1.36
80
60
20
PERCENTAGE
BRAZEAU
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

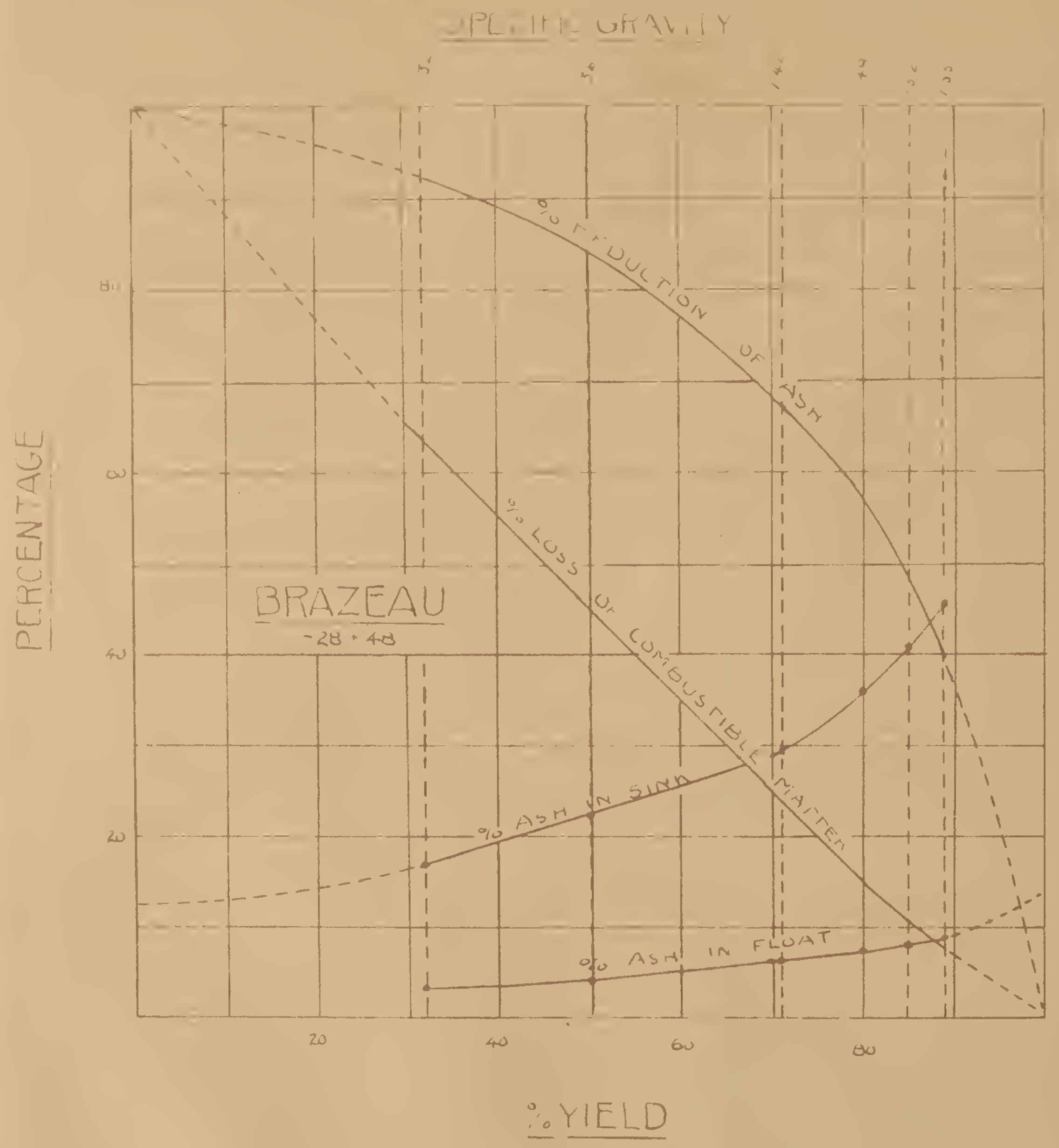
80
PERCENTAGE
BRAZEAU
20

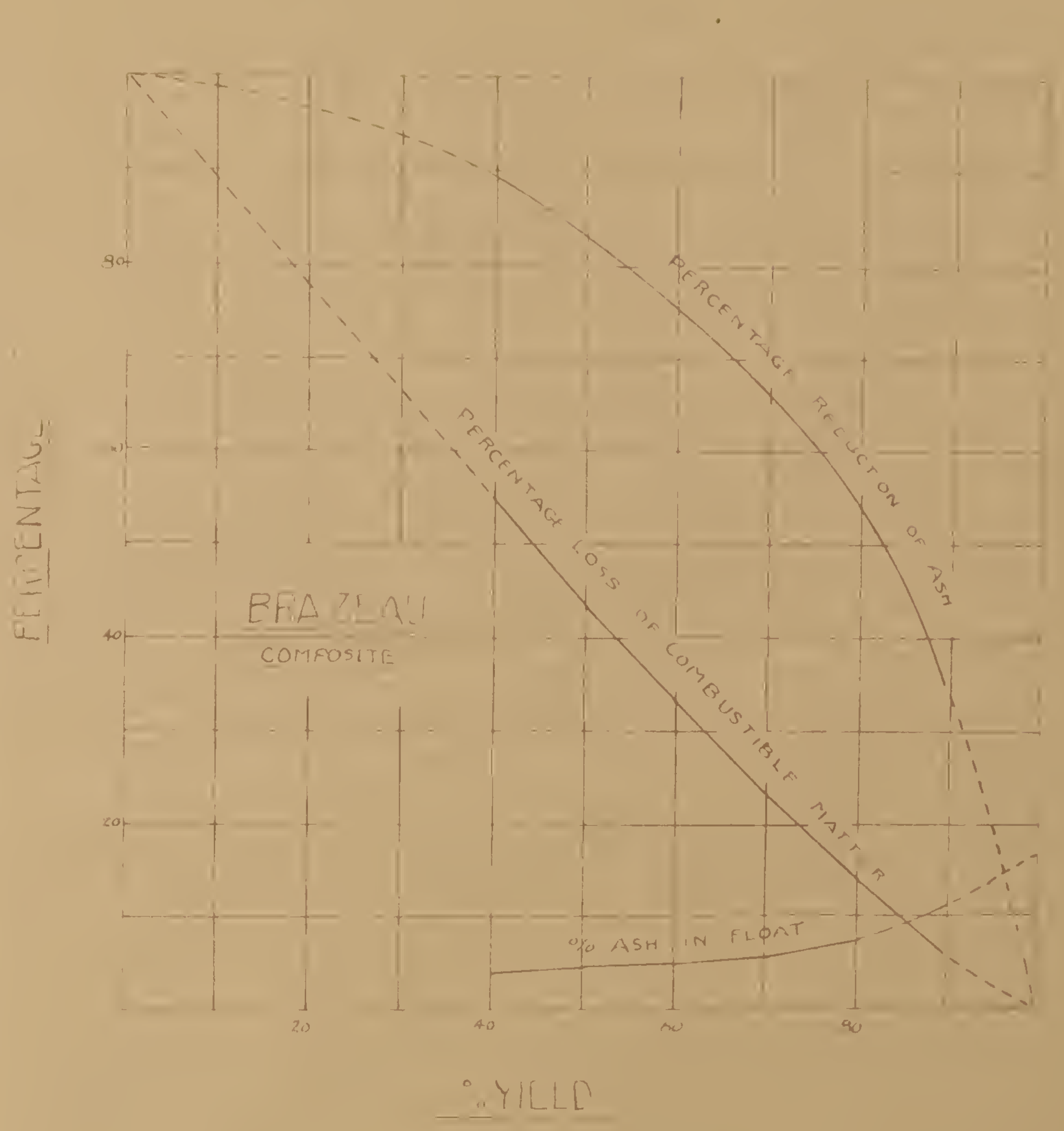
SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
% REDUCTION OF

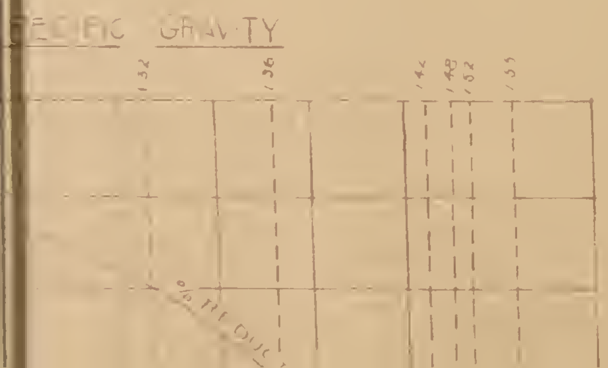

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.53
80
% REDUCTION OF

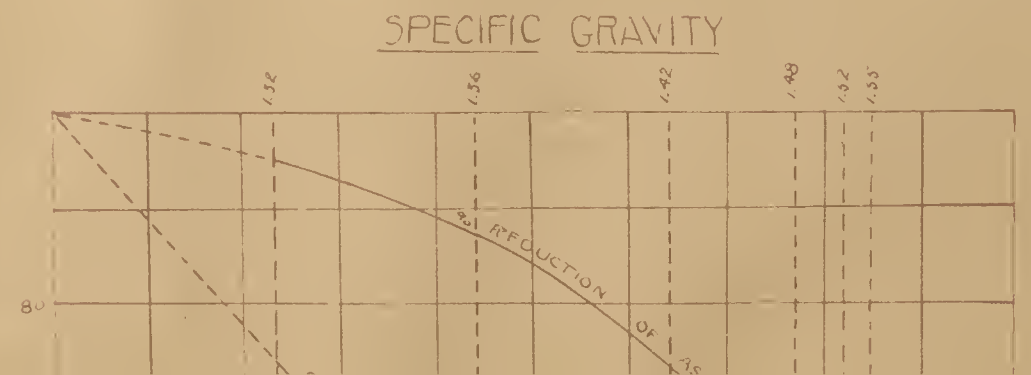


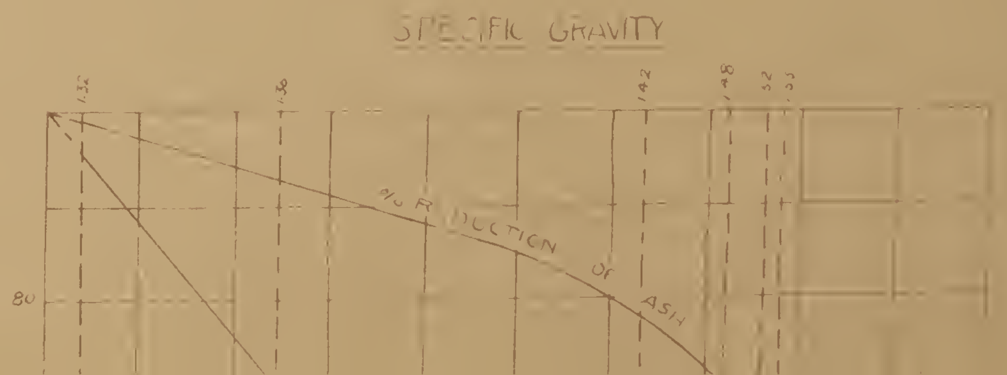

SPECIFIC GRAVITY
REDUCTION OF ASH
% ASH IN SINK
LOSS OF COMBUSTIBLE MATTER
% ASH IN FLOAT
60
80
% YIELD

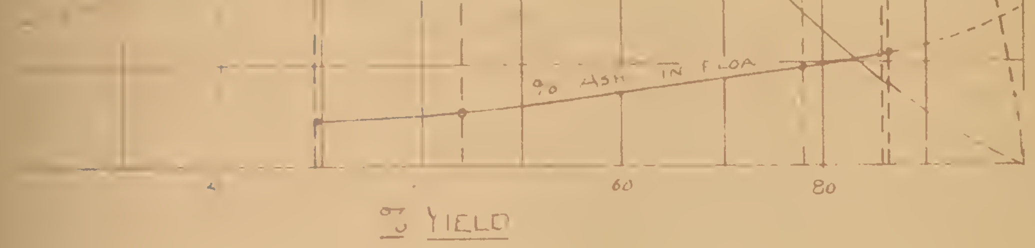

SPECIFIC GRAVITY
PERCENTAGE
BRAZEAU
-28 + 48
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
80
60
40
20
20
40
60
80
% YIELD

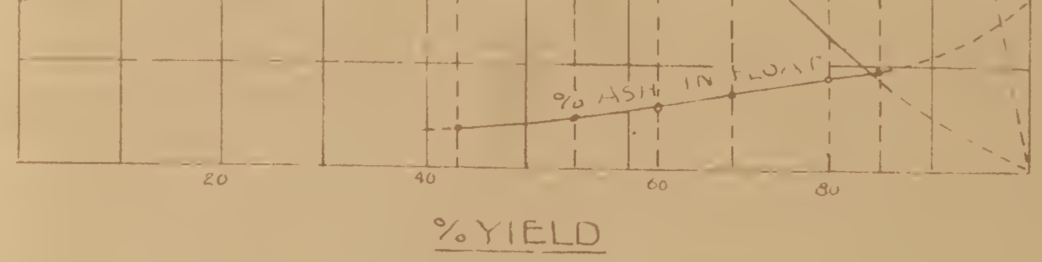

PERCENTAGE
BRAZEAU
COMPOSITE
PERCENTAGE REDUCTION OF ASH
PERCENTAGE LOSS OF COMBUSTIBLE MATTER
% ASH IN FLOAT
80
40
20
20
40
60
80
% YIELD

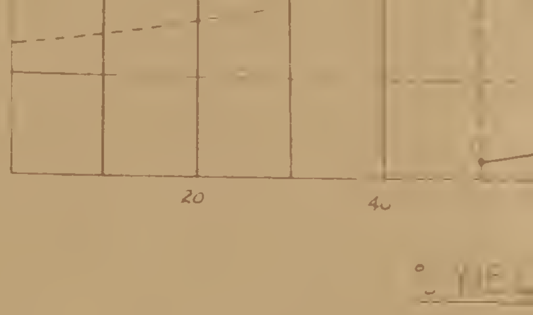

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
% REDUCTION

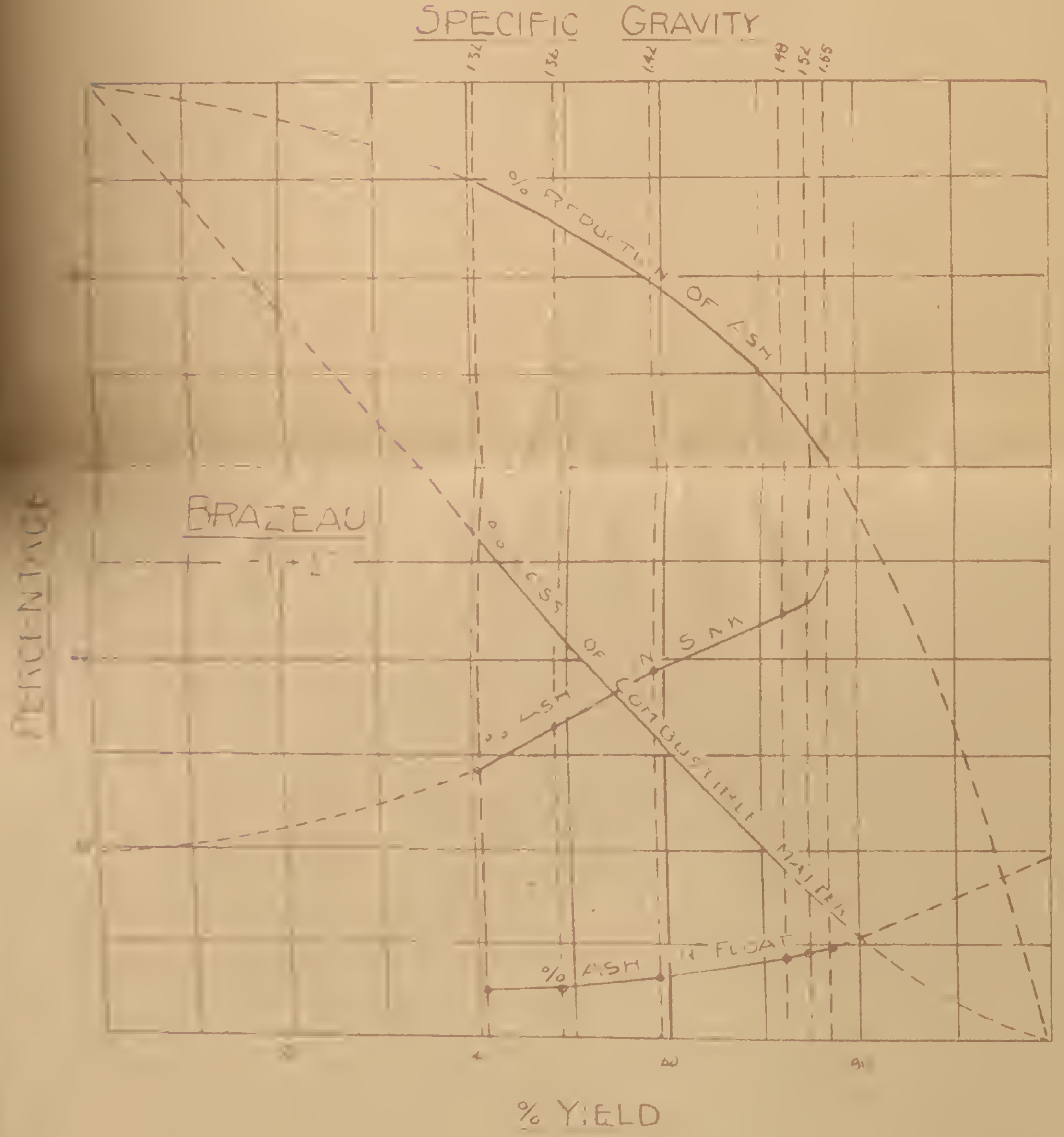

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80
% REDUCTION OF ASH

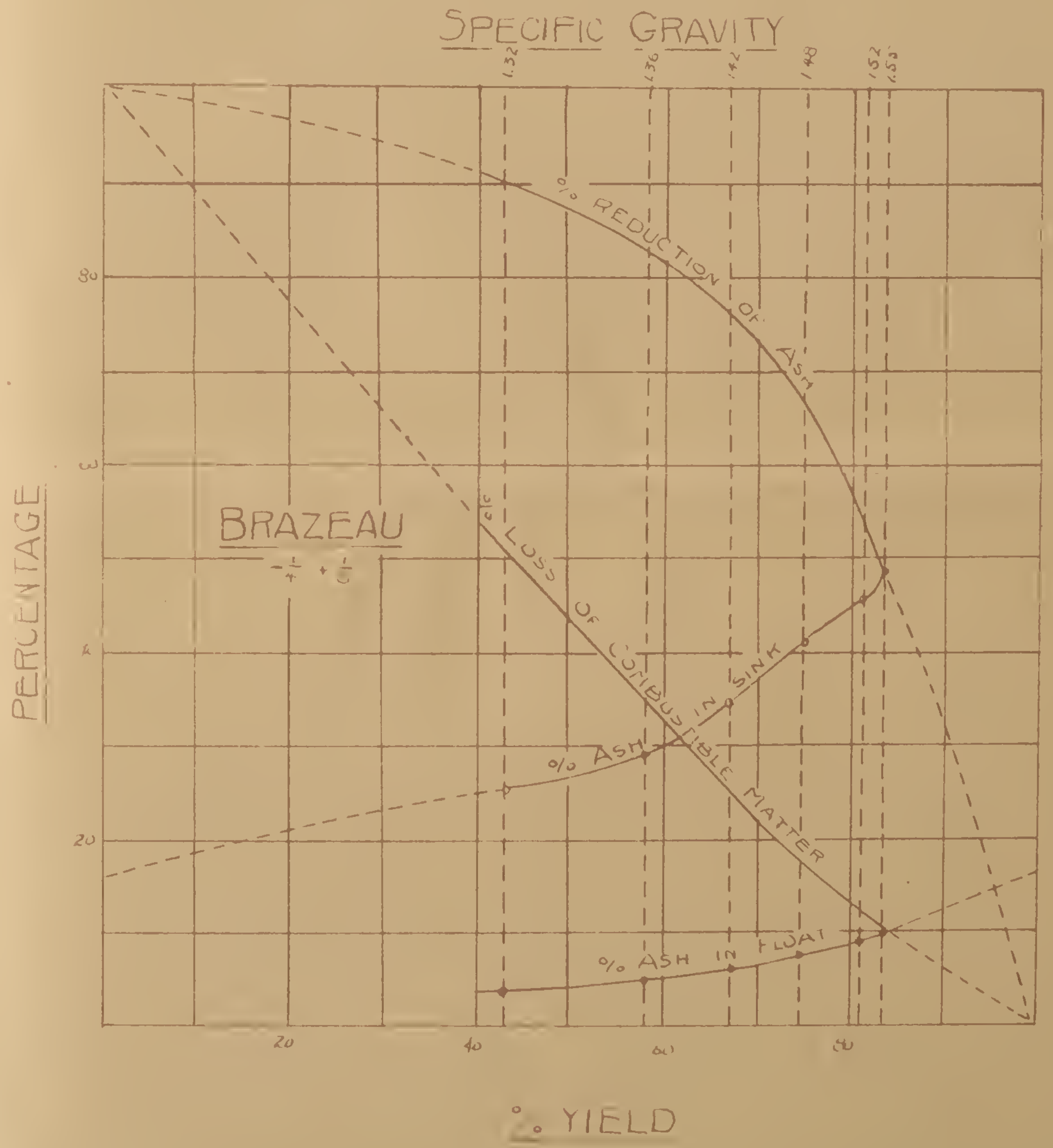

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80
% REDUCTION OF ASH

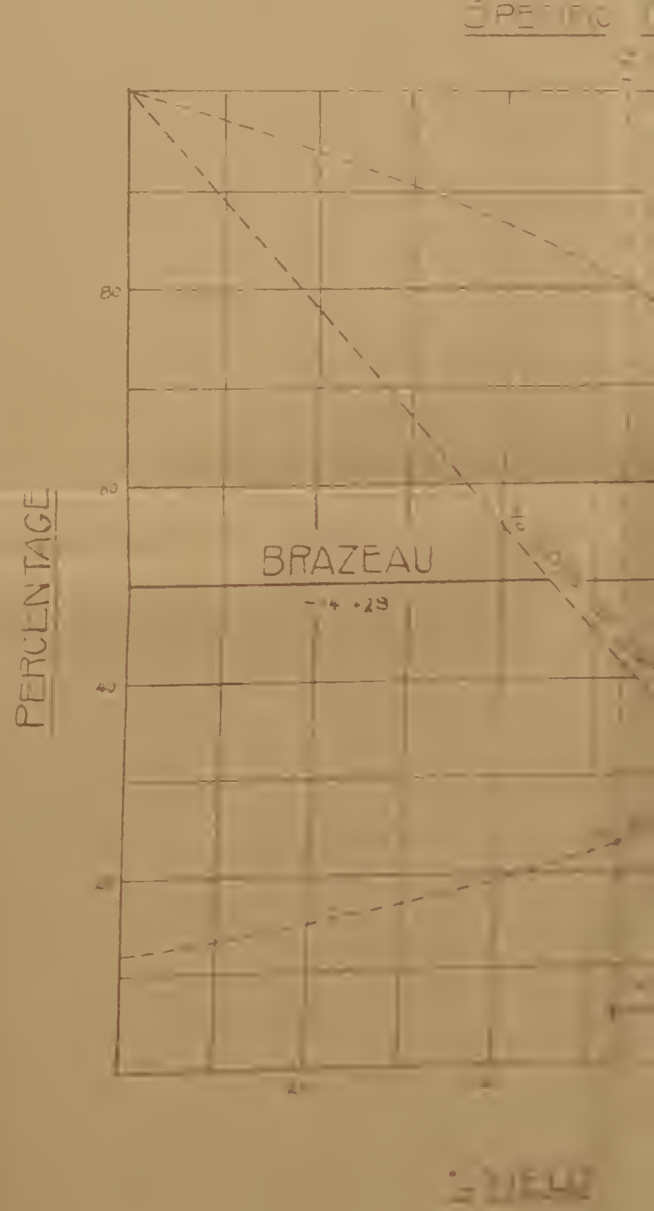

% ASH IN FLOAT
60
80
% YIELD

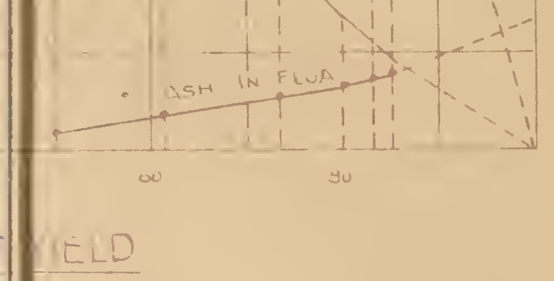

% ASH IN FLOAT
20
40
60
80
% YIELD

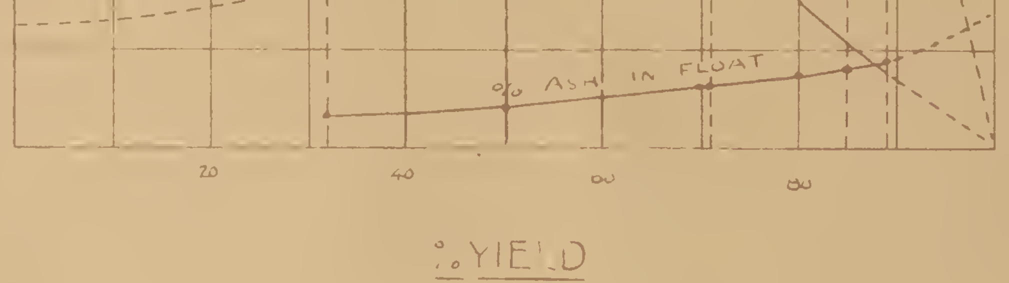

20
40

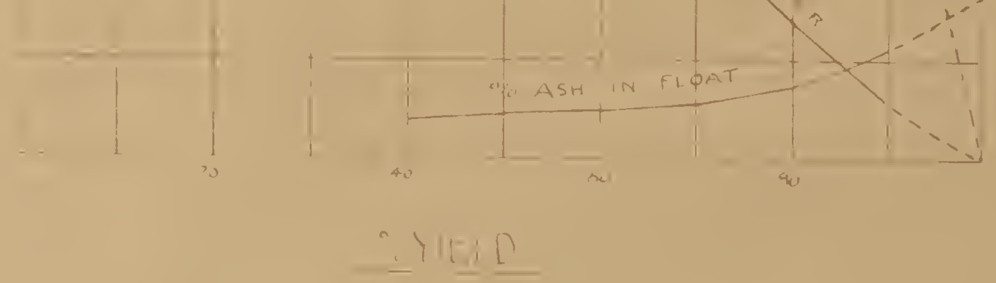

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.65
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
BRAZEAU
PERCENTAGE
% YIELD
60
80

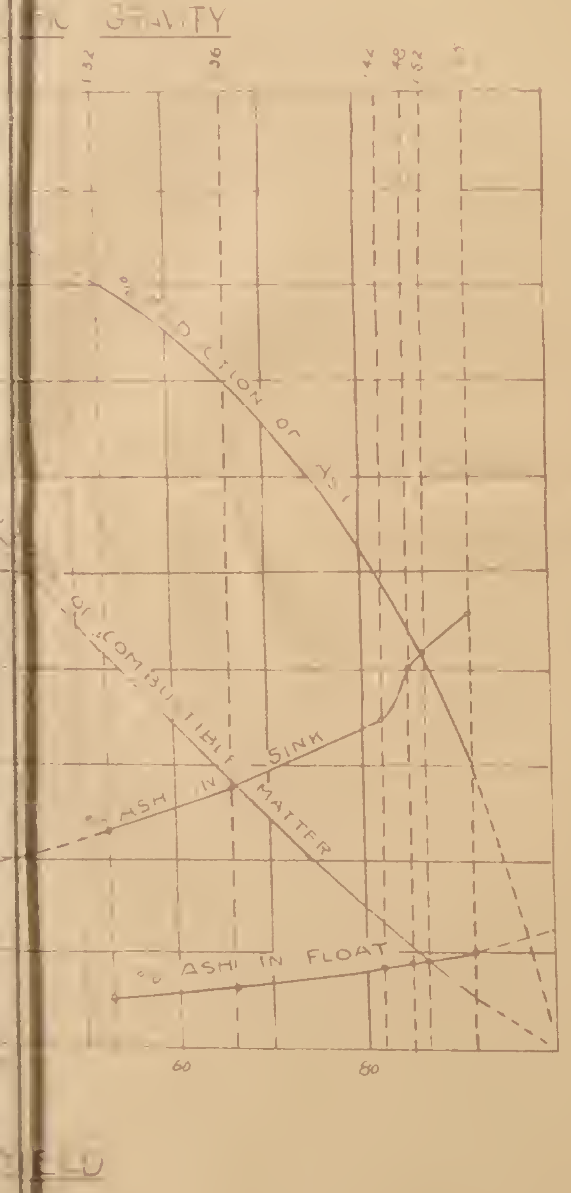

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
BRAZEAU
PERCENTAGE
80
20
20
40
60
80
% YIELD

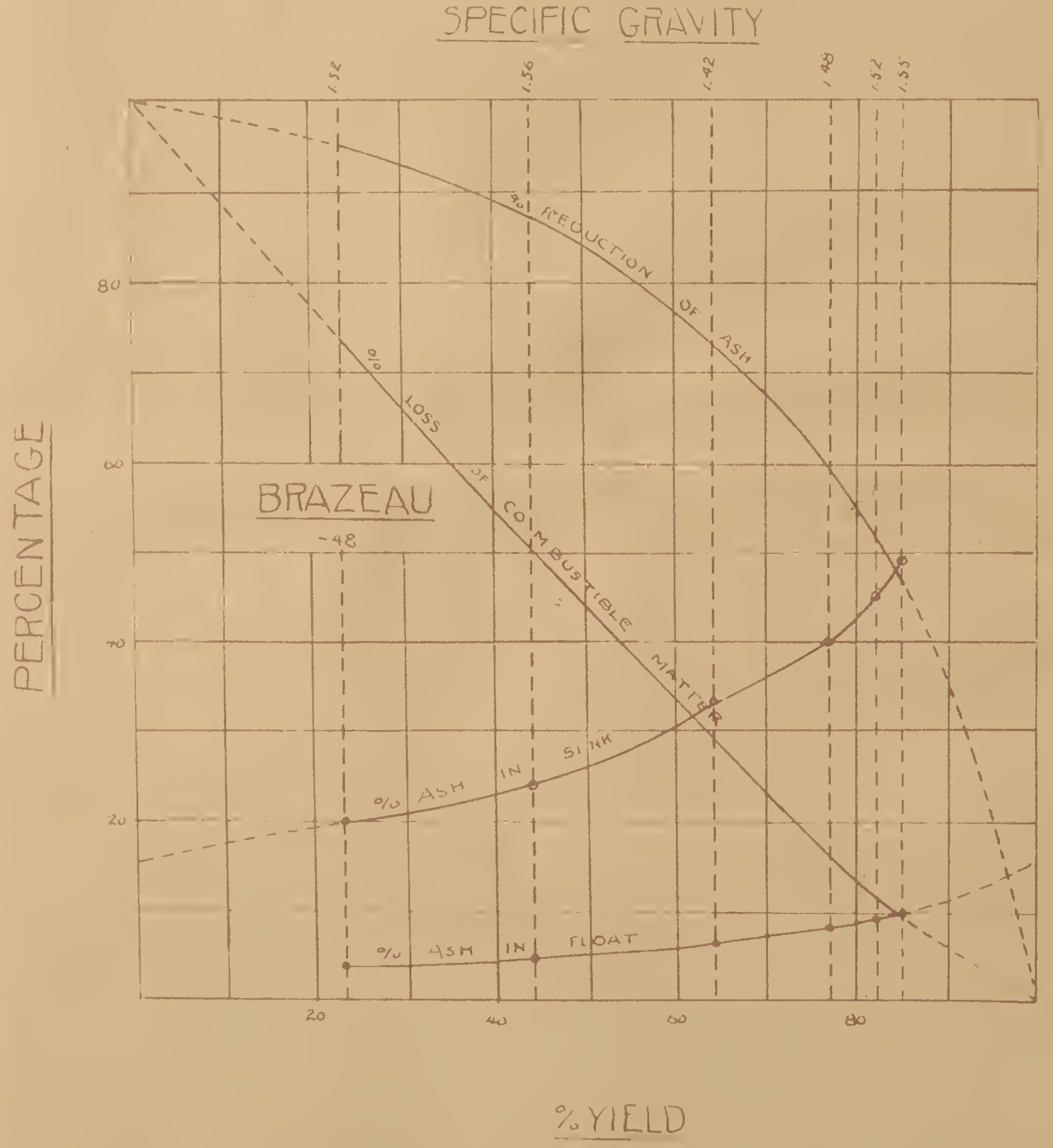

SPECIFIC
BRAZEAU
PERCENTAGE
80
% YIELD

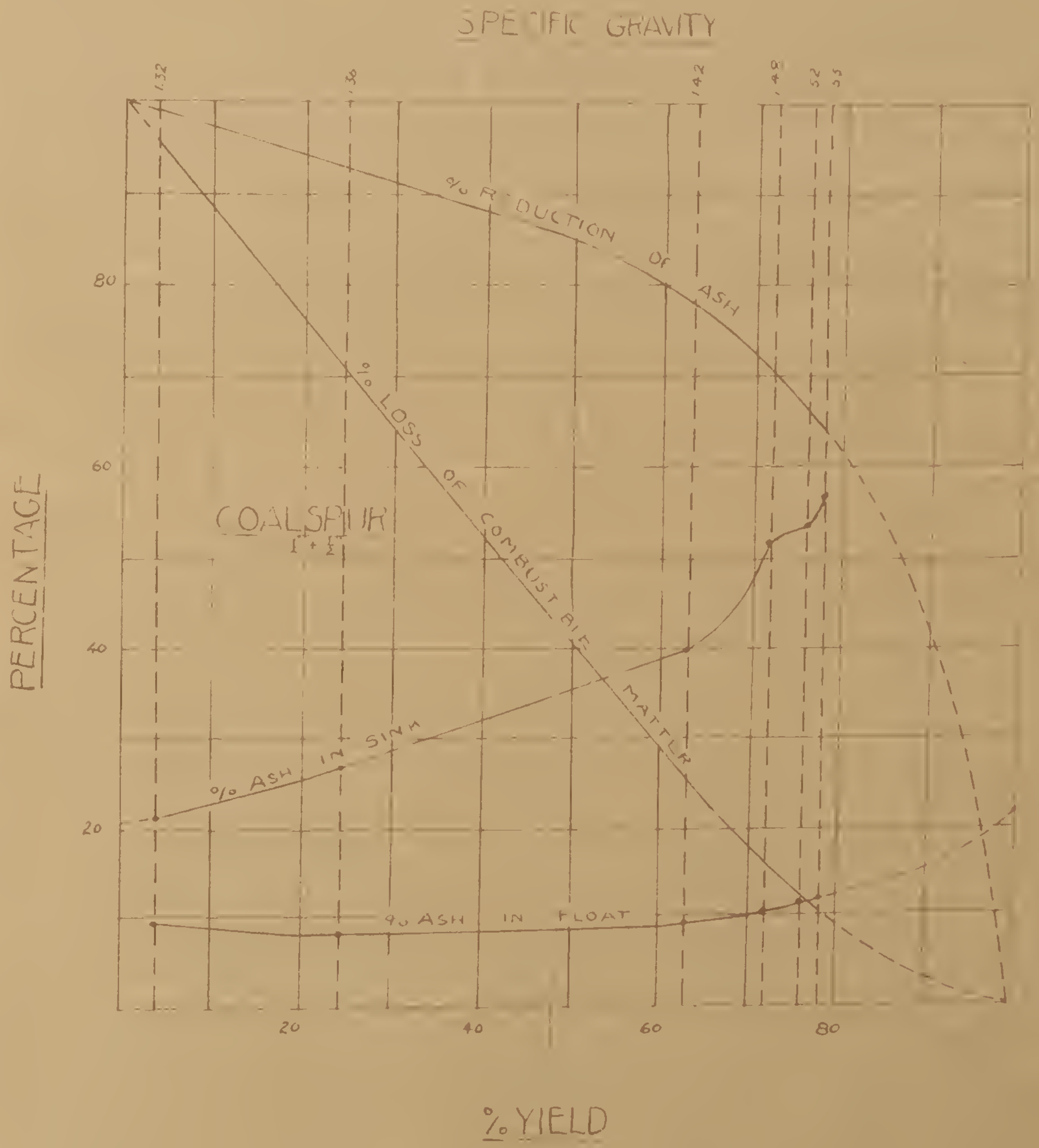

% ASH IN FLOAT
60
80
YIELD


% ASH IN FLOAT
20
40
60
80
% YIELD


% ASH IN FLOAT
20
40
60
80
% YIELD


GRAVITY
1.32
1.36
1.42
1.48
1.52
% REDUCTION OF ASH
OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
60
80
YIELD


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80
60
40
20
PERCENTAGE
BRAZEAU
-48
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80
60
40
20
PERCENTAGE
COALSPUR
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

The material heavier than 1.55 specific gravity was commonly present in flat lumps which would tend toward an easy separation of these impurities in such types of cleaning equipment as the spiral separator. There was a great deal of fine slack in the run of mine sample as about 58% passed the 8 mesh screen. The fine sizes were the cleaner indicating that the coal was more friable than its localized impurities.

The float and sink tests were made on eight sizes by the divided sample procedure. The results are shown graphically on page 47. From these it can be seen that about 65% of the material was lighter than 1.42 specific gravity, about 25% between 1.42 and 1.55, and about 10% greater than 1.55. In most sizes the specific gravity distribution is relatively small between 80 and 90% yields, which denotes this as the most favourable point of separation as far as the absence of middlings is concerned. The widest specific gravity range was found for the largest and smallest sizes, indicating that the intermediate sizes are more easily cleaned.

The curves showing the reduction of ash, and loss of combustible matter, are similar for all the sizes. From the composite curve, an 80% recovery gives a cleaned coal with 7% ash, a loss of 12% of the combustible matter in the discard, and an ash reduction of 54%. A 90% recovery indicates a cleaned coal of 11% ash, a loss of 6% of the combustible matter in the discard and an ash reduction of about 34%.

The mine run would be hard to clean because of the large amount of fines contained. The larger sizes show satisfactory ash reduction. The bypassing of all the fines and addition to the other sizes after cleaning would not prove very satisfactory if a considerable reduction of ash is desired.

The differences in the washability curves of the eight sizes of this

coal are seen to be very small and hence did not justify such a close sizing range for these tests. It was decided to reduce the number for the other coals and to choose sizing limits that would closely approximate general commercial practice.

Brazeau #2. A second series of five tests were made on the Brazeau sample for the purpose of comparing the divided method first employed, with the unit method of procedure.

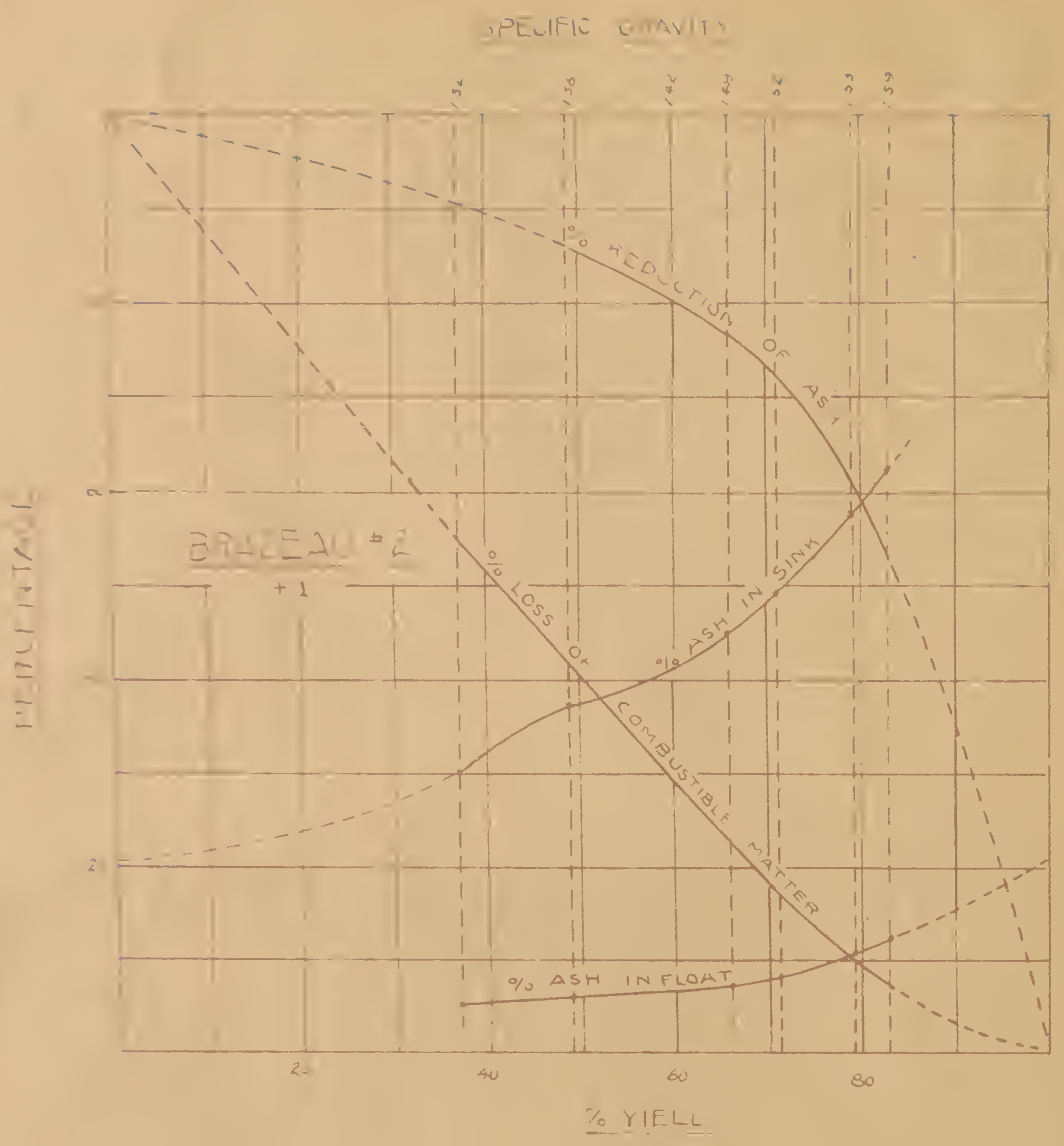
The screen analyses of the two Brazeau samples are not closely comparable, as different screens were used. In the washability tests, the only size common to both methods is the ½" to 1". This is therefore used for comparison and also the composite for the run of mine coal. Composites of ½" to 8 mesh, and 8 to 28 mesh might also have been calculated and compared.

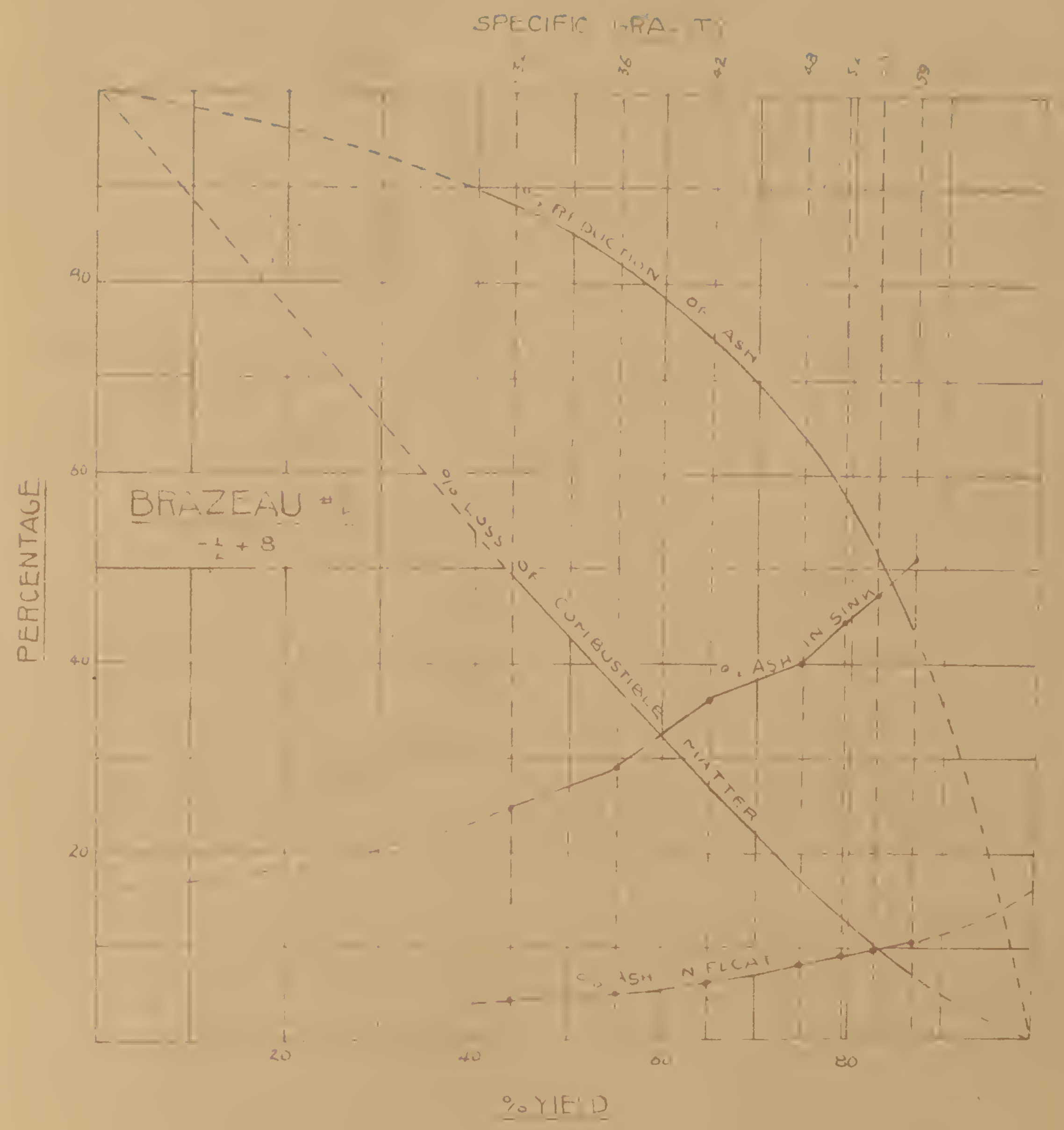
The composite washability curves obtained by the second or unit sample method, page 50, are very similar to those by the divided method, while the curves for ½" to 1" sizes are almost identical. The specific gravity distribution as determined by the unit procedure, as by the earlier method, indicated that the intermediate sizes would be the more easily cleaned.

From these results it may be assumed that, if a representative sample were taken in each case, there would be no great difference between the results obtained by the two methods. Nevertheless, it is recommended that as uniform a procedure as possible be adopted for all tests.

Section III. Coalspur. The only size available for washability tests on this coal was that passing 1 inch and retained on ½ inch screens. This contained 21% ash.

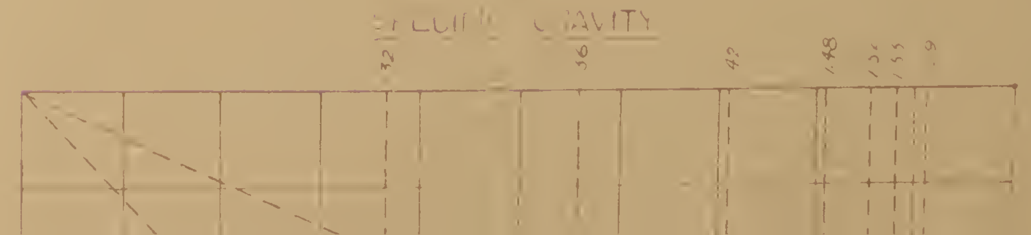
The specific gravity distribution was found by the divided sample method (diagram page 47), shows that 63% of the material is less than 1.42 specific gravity and contains about 9% ash, that 15% is between 1.42 and 1.55

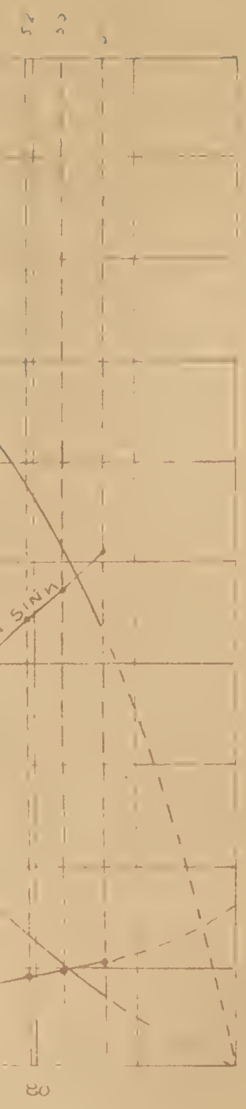

SPECIFIC GRAVITY
1.34
1.38
1.42
1.45
1.52
1.55
1.59
PERCENTAGE
BRAZEAU #2
+1
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

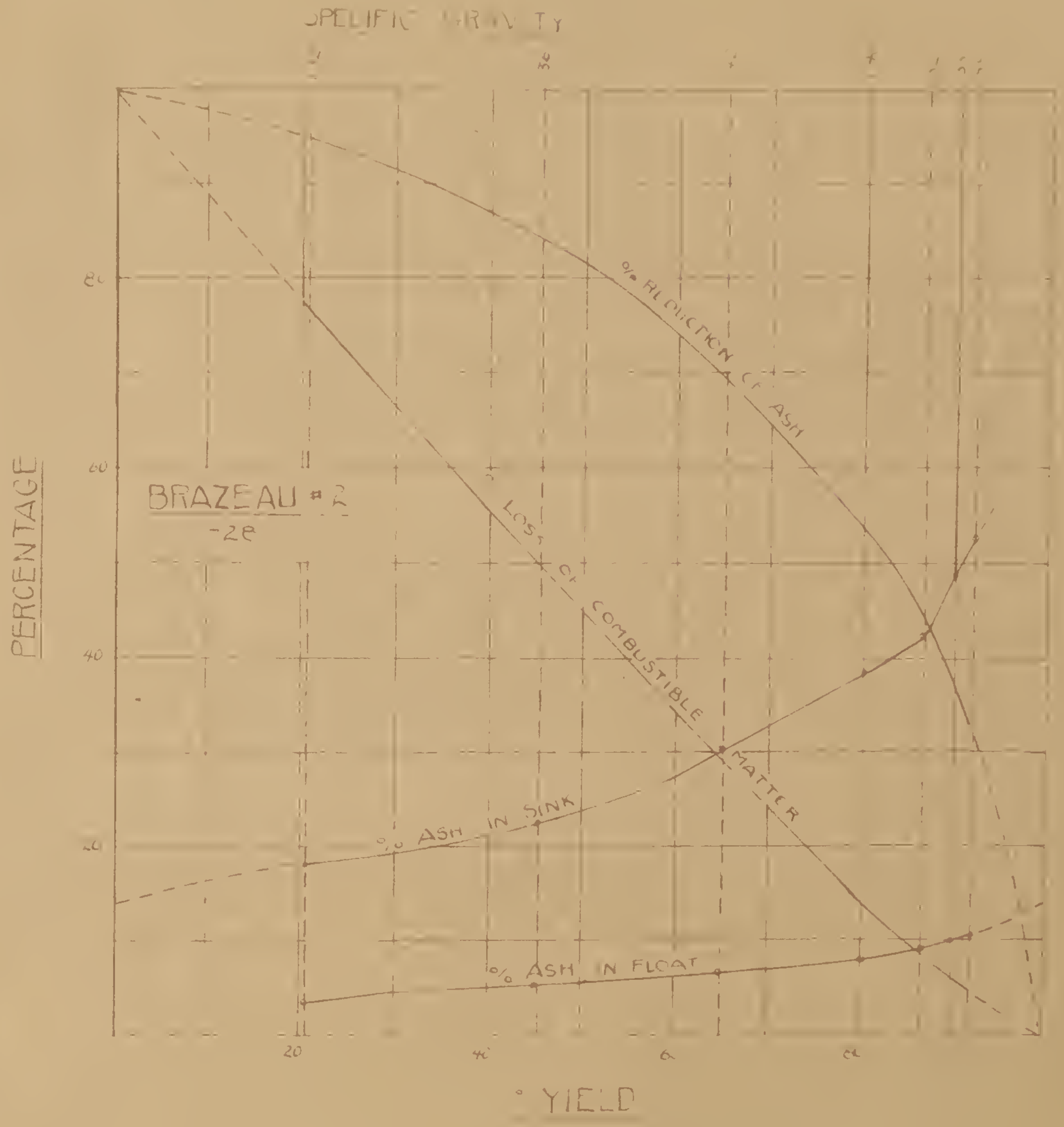

SPECIFIC GRAVITY
36
42
48
59
80
60
40
20
PERCENTAGE
BRAZEAU
+8
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

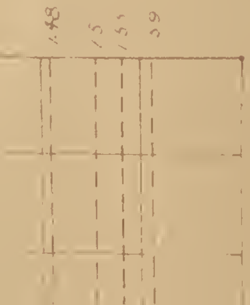
PERCENTAGE

SPECIFIC GRAVITY
1.42
48
1.52
55
59

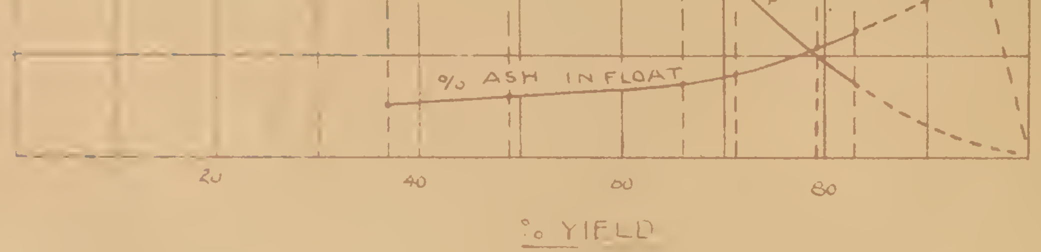

SPECIFIC GRAVITY
32
36
42
1.48

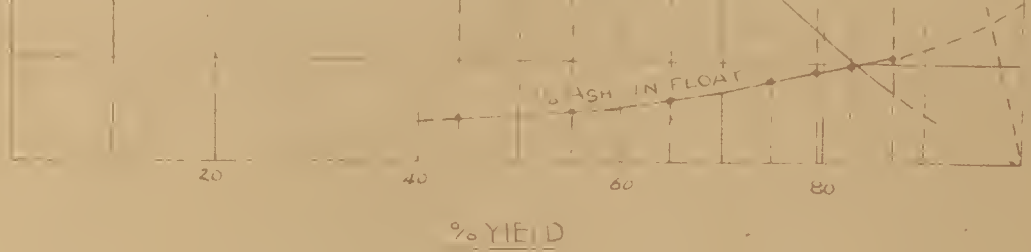

SINK
80

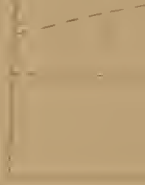

SPECIFIC GRAVITY
PERCENTAGE
BRAZEAU # 2
-28
% REDUCTION OF ASH
LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
80
60
40
20
20
40
60
80
% YIELD

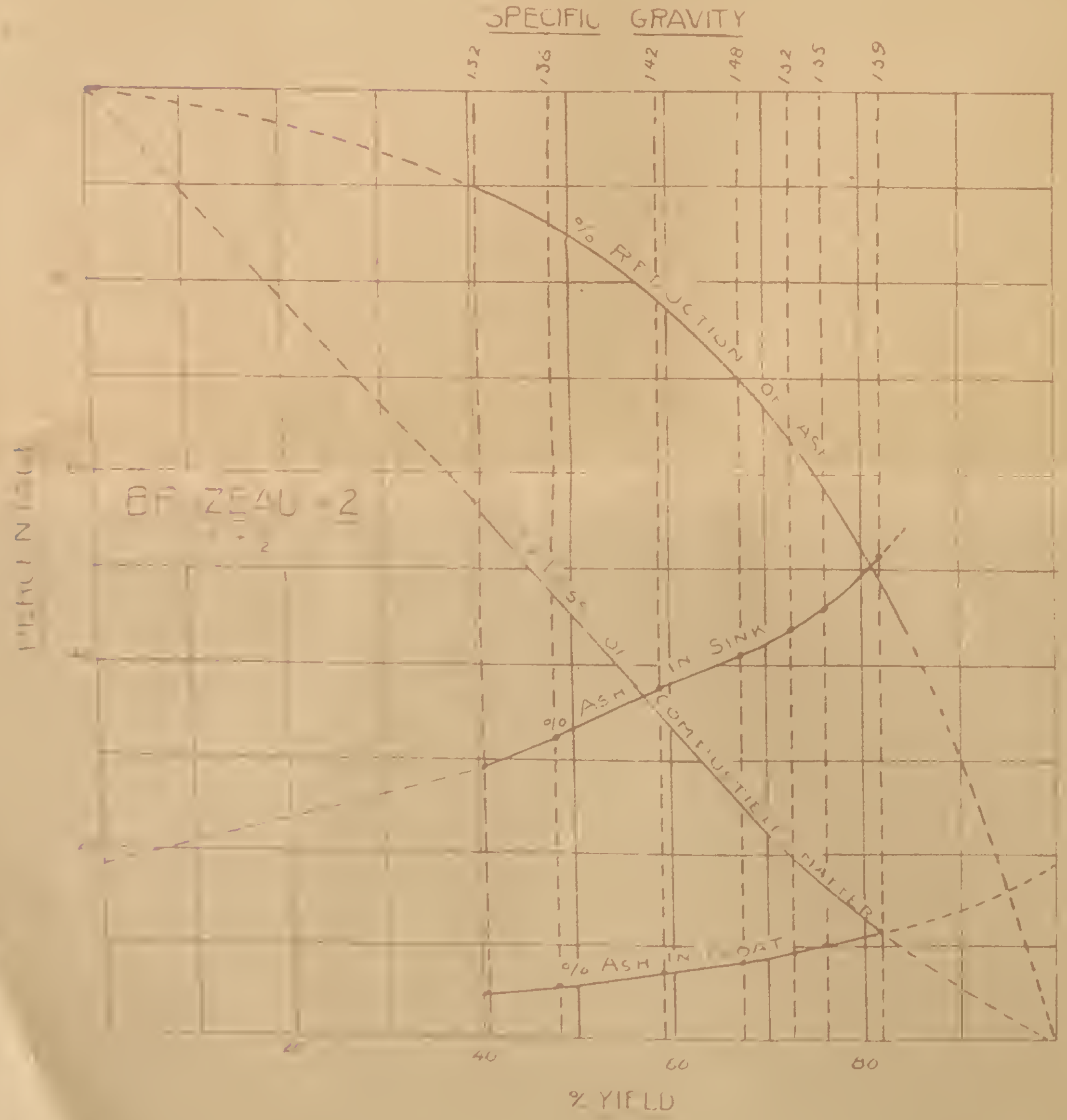

1.48
1.5
1.55
1.59

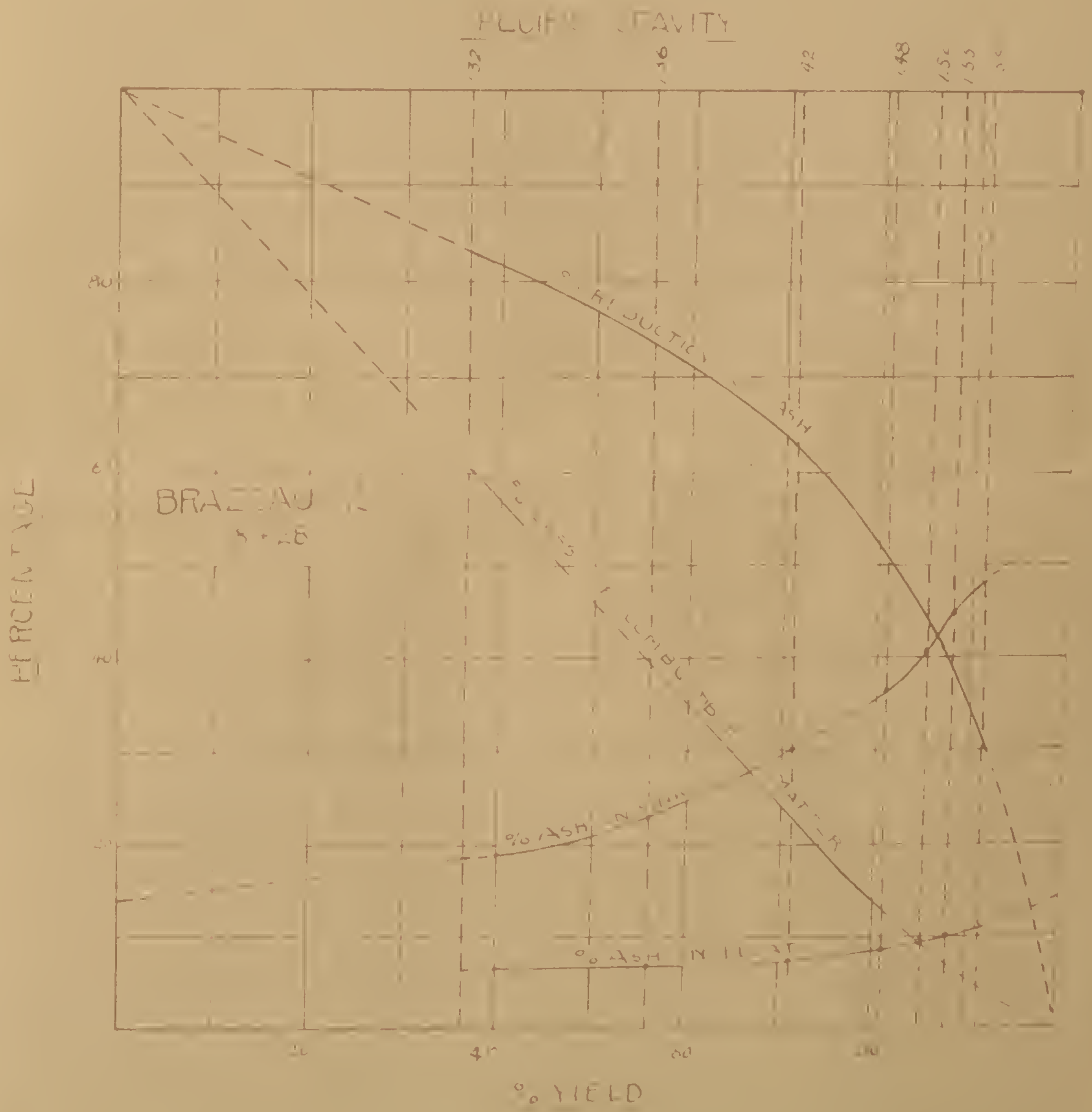
SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
80

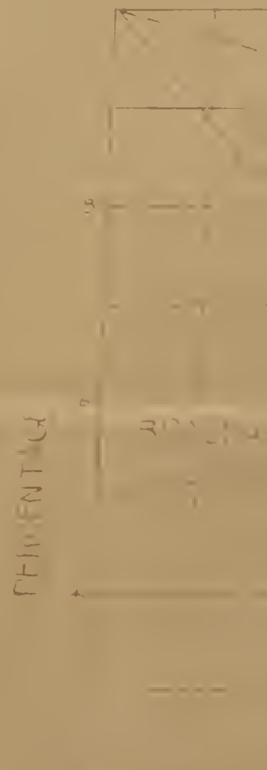

% ASH IN FLOAT
20
40
60
80
% YIELD


% ASH IN FLOAT
20
40
60
80
% YIELD

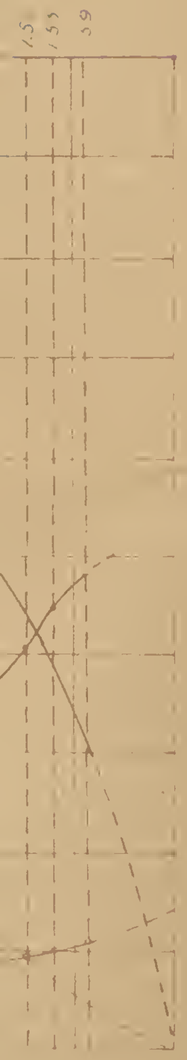


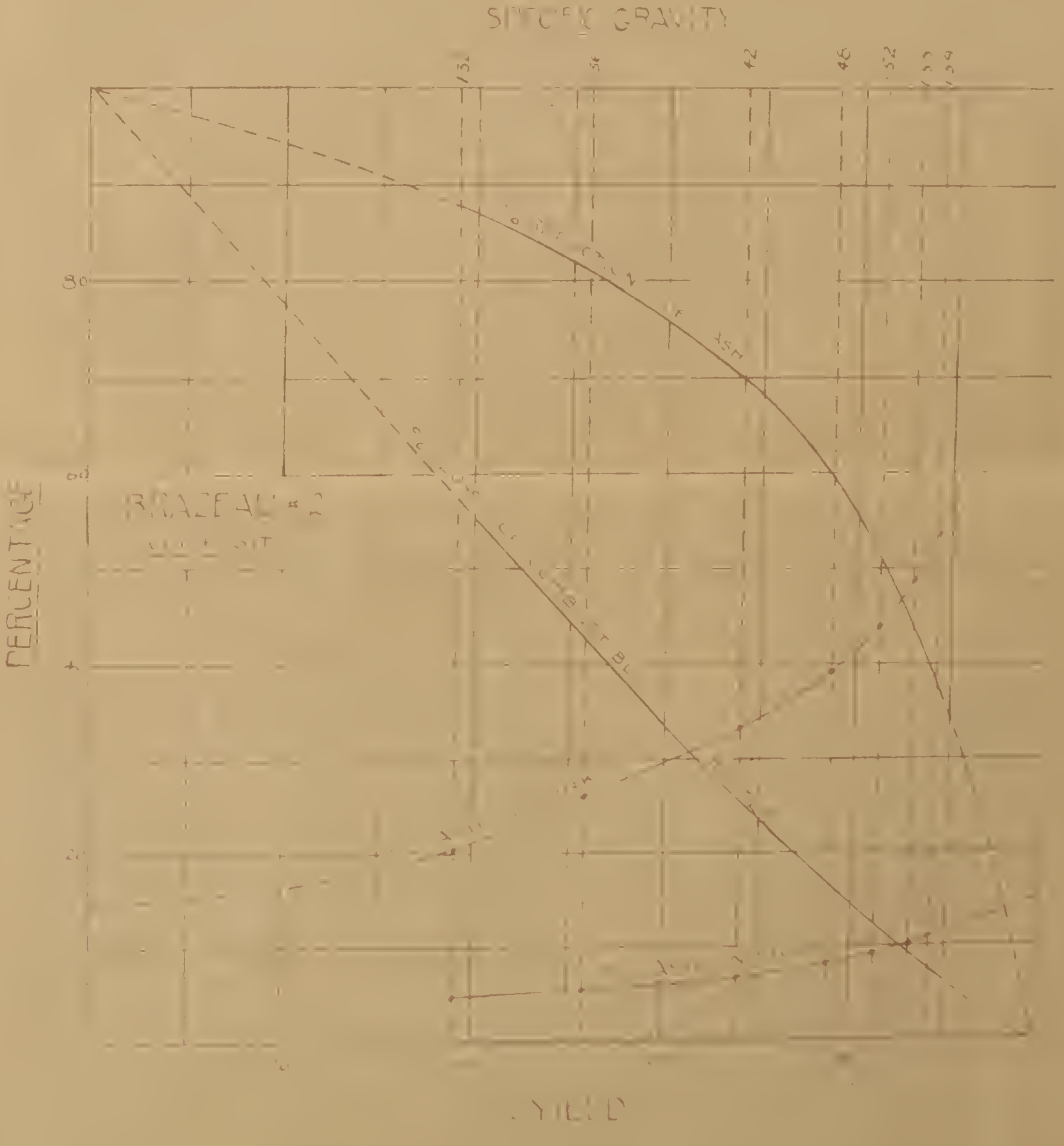

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
% REDUCTION OF ASH
BRAZEAU 2
PERCENTAGE
% ASH IN SINK
% ASH OF COMBUSTIBLE MATTER
% ASH IN FLOAT
20
40
60
80
% YIELD


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
% REDUCTION OF ASH
BRAZEAU
PERCENTAGE
80
60
40
% ASH OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD


PERCENTAGE

20
4
6
8
% YIELD


1.5
1.55
1.59


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
80
60
40
20
PERCENTAGE
BRAZEAU # 2
% YIELD

specific gravity, and that 22% is greater than 1.55 specific gravity with 57% ash.

The curves showing percentage reduction of ash and percentage loss of combustible matter are widely separated indicating favorable ash reduction with small loss of clean coal. A recovery at 1.55 specific gravity or 78% yield represents a cleaned coal of 12% ash, a 10% loss of combustible matter in the discard and an ash reduction of 63%. The percentage ash in float curve shows that it would be useless to attempt to reduce the ash below 8%, an amount which evidently approximates closely the amount of disseminated impurities in the coal. The most suitable recovery would appear to be between 70 and 80%, since yields less than this would result in heavy loss of combustible matter.

A run of mine sample from this mine tested at Ottawa, Strong[14], showed an equal ash content. This sample indicated that successive sizes from 6 to 48 mesh increased from 19.3 to 26.4% ash, but that no appreciable ash reduction was effected by any system of screening. In the washing trials made at Ottawa the amount run seems to be too small to be reliable. It is stated that difficulty would be experienced in reducing the ash content below 15% by flotation or by ordinary table methods.

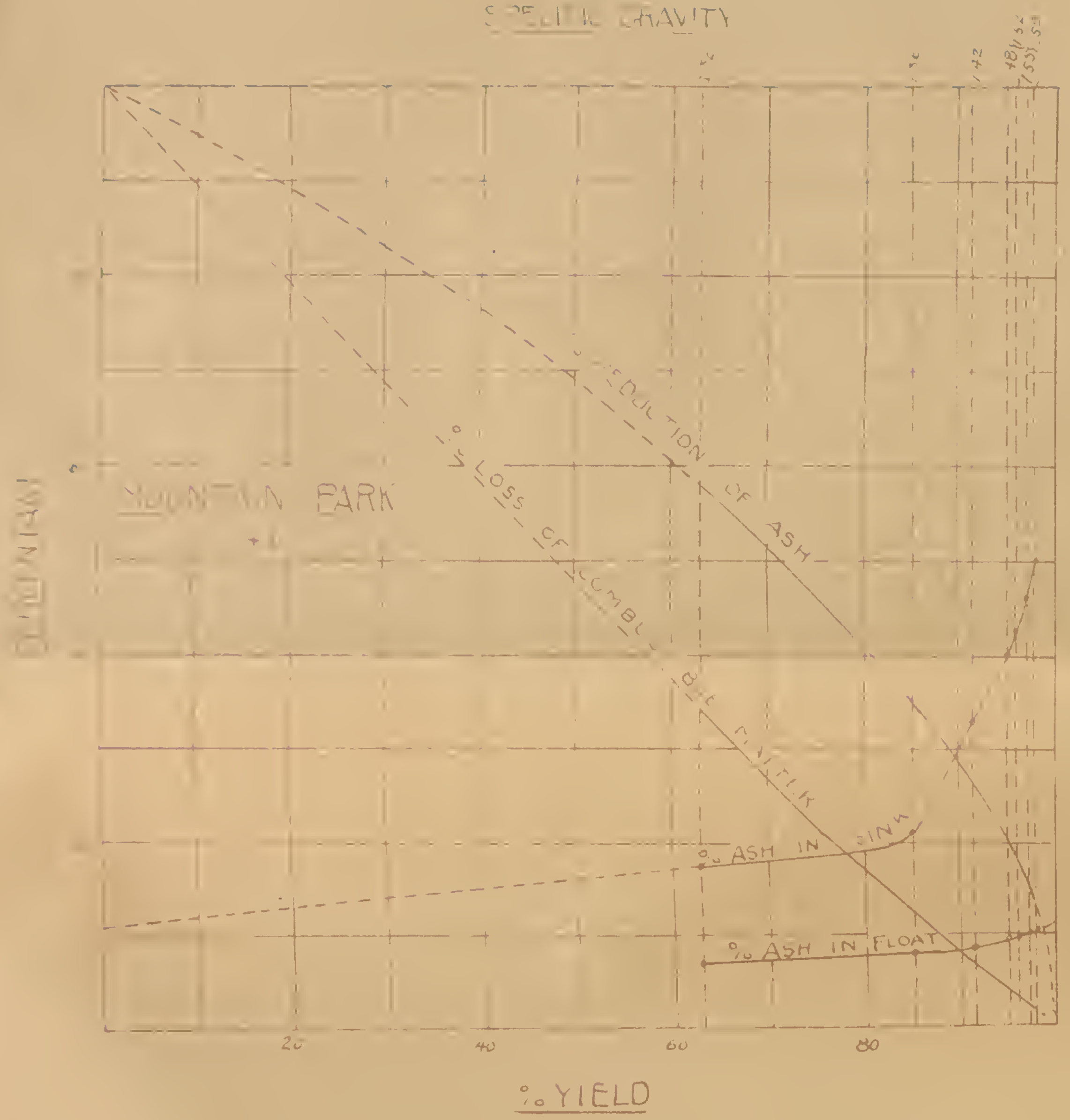
Section IV. Mountain Park. This sample appeared to be composed largely of bright rounded particles with only a few pieces of shale or other visible impurities. About 35% of the sample was retained on the one inch screens while the -8 mesh fines made up about 17%. The ash contents of the various sizes were remarkably constant, although that for the ½" to ¼" size was slightly more than those for the other four sizes. The curves showing cumulative percentage ash are in consequence almost coincident at all points.

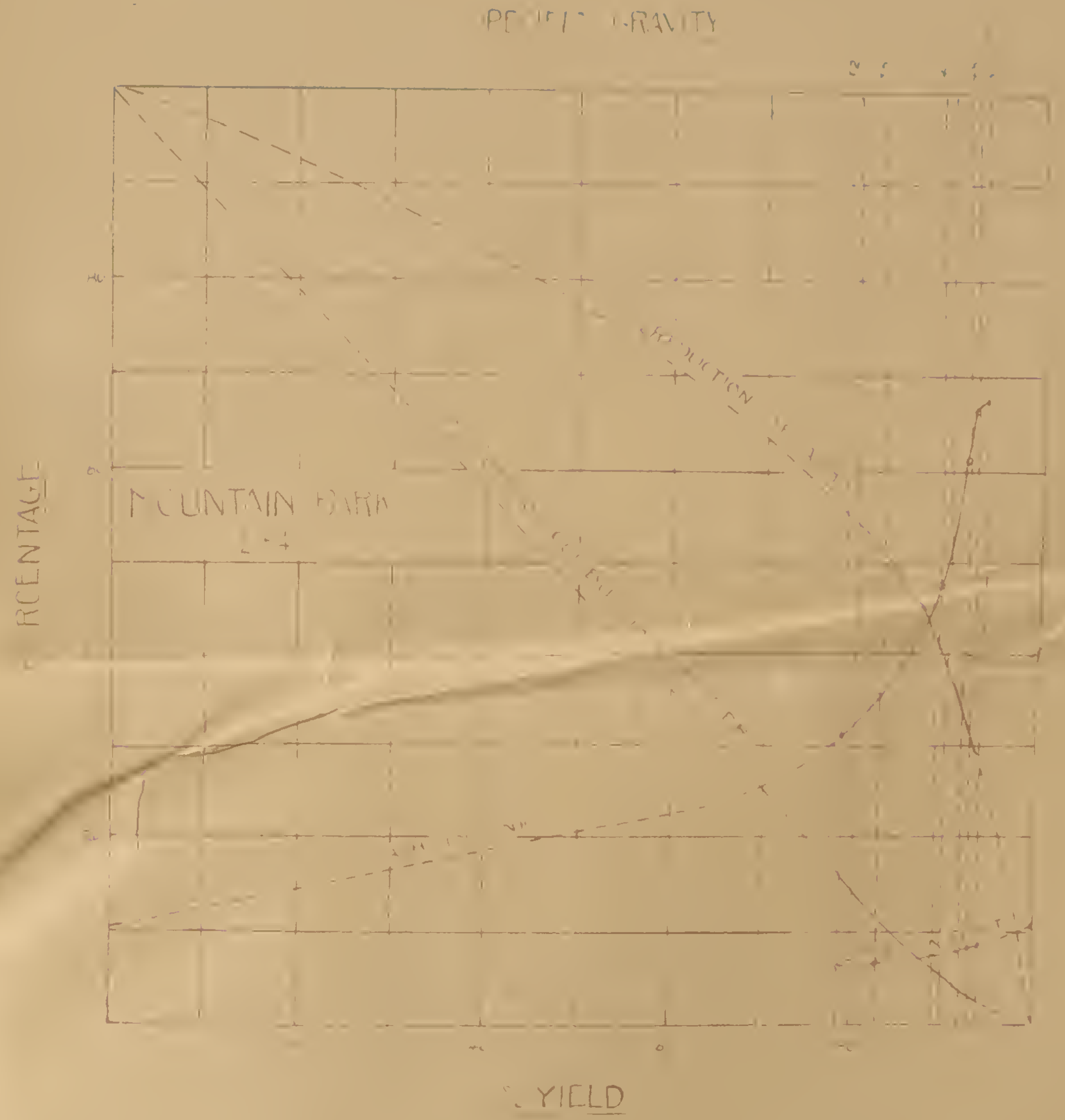
The ash content of the total sample was very low, and it is unlikely that such coal would be cleaned.

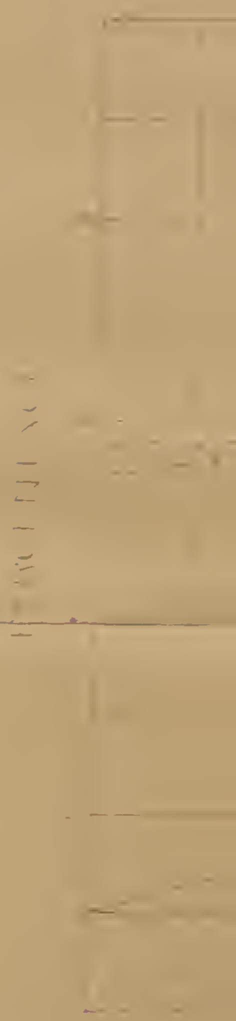
The coal is characterized by a high percentage of light clean particles, as the specific gravity distribution, composite page 53, indicates that 90% of the sample is less than 1.42 specific gravity, 5% between 1.42 and 1.55 specific gravity and 5% greater than 1.55 specific gravity. The specific gravity lines are close together between 90 and 100% recovery showing that a favorable separation could be made within these limits. A washing yield of 95% would give a cleaned coal with 8% ash. This involves a 2% loss of combustible matter, a 39% reduction of ash, and the discard would contain 60% ash. The proximity of the specific gravity lines indicates a very small proportion of middlings at this yield.

There is a much wider spread of specific gravity distribution in the 1 inch size than in the others, and the proportion of middlings decreases with size until in the $\frac{1}{4}$ inch to 8 mesh size the material between 1.32 and 1.59 specific gravity comprises only 9% of the whole. With the coal larger than 1 inch, no notable reduction of ash can be made without serious loss of combustible matter. For any given reduction of ash, the finer the coal, the smaller is the consequent loss of combustible matter. This would suggest the advisability of crushing the coal to bring about a more complete separation if it were not for the increased difficulty of cleaning fine coal. The low friability of the coal as estimated from screen analysis, and the small amount of middlings found in the tests, suggest that dirty coal from this mine should be easily cleaned.

Section V. Luscar. This sample of coal seemed to be very clean with very few particles of visible impurities. A large proportion of fusain was easily

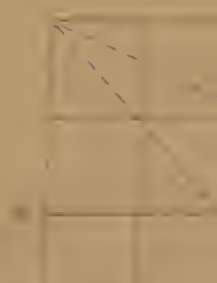

SPECIFIC GRAVITY
PERCENTAGE
MOUNTAIN PARK
REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

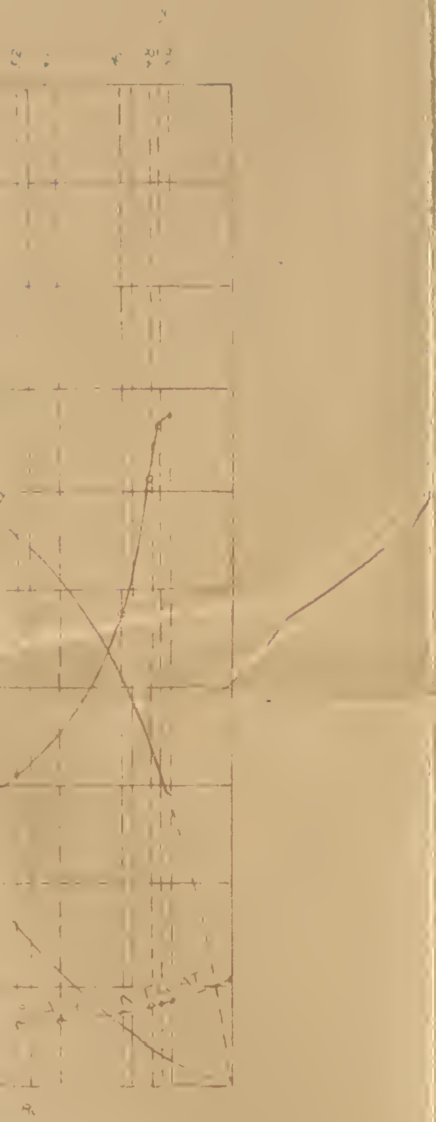

SPECIFIC GRAVITY
PERCENTAGE
MOUNTAIN PARK
REDUCTION OF ASH
% YIELD

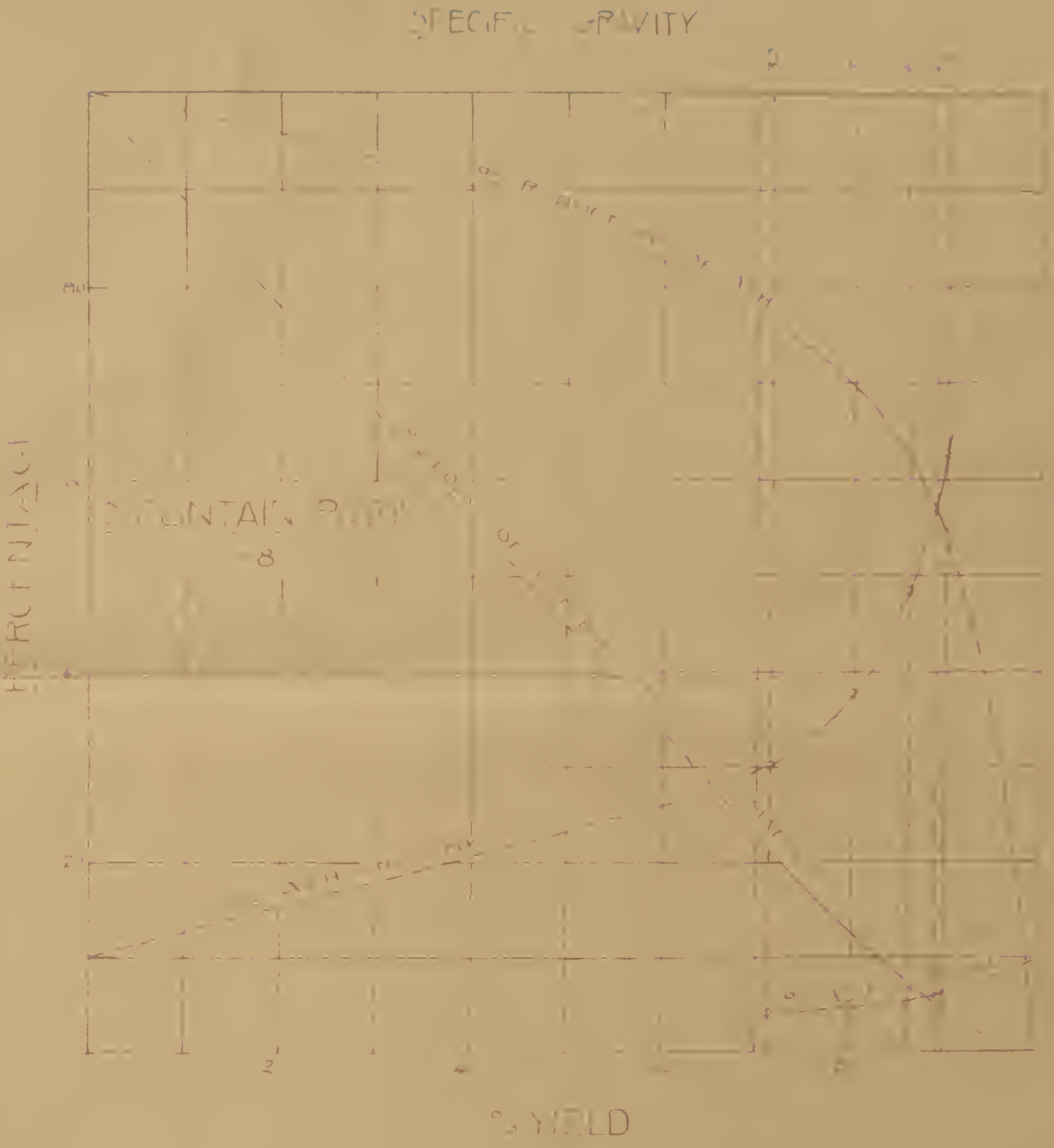


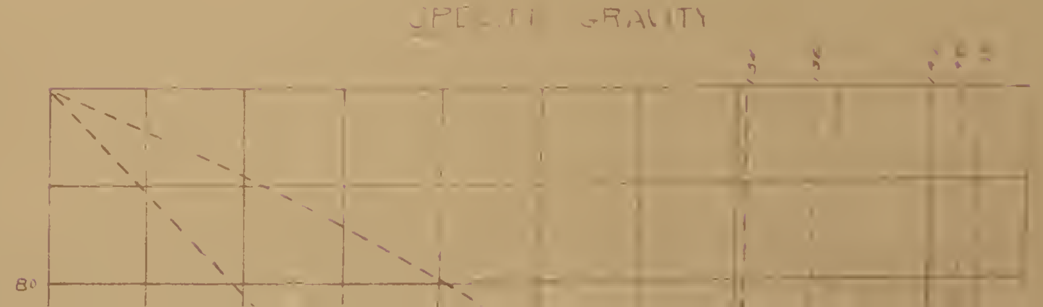
SPECIFIC GRAVITY

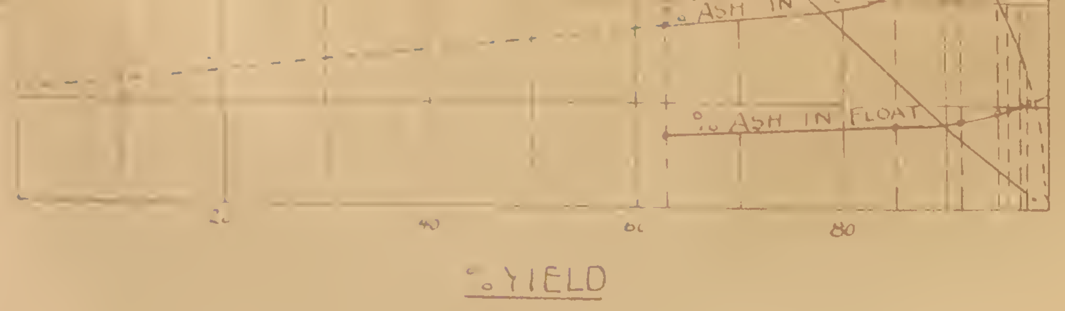
SPECIFIC GRAVITY

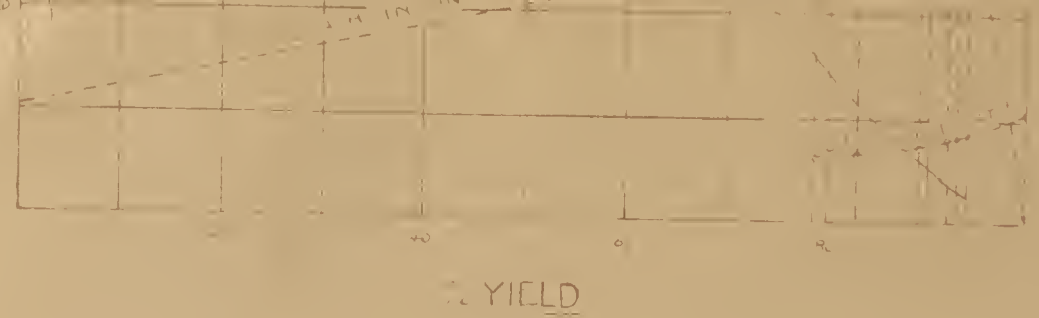


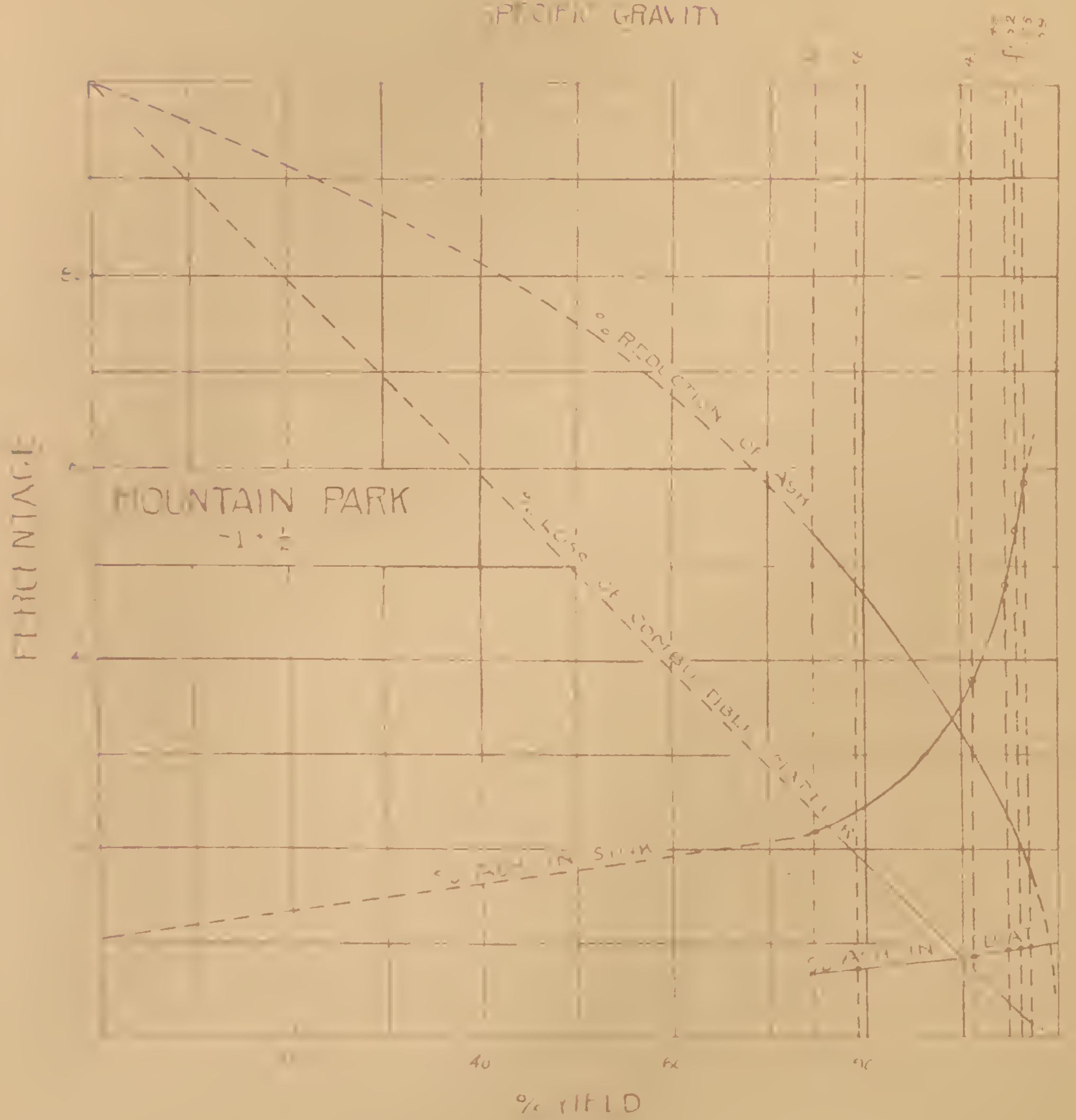


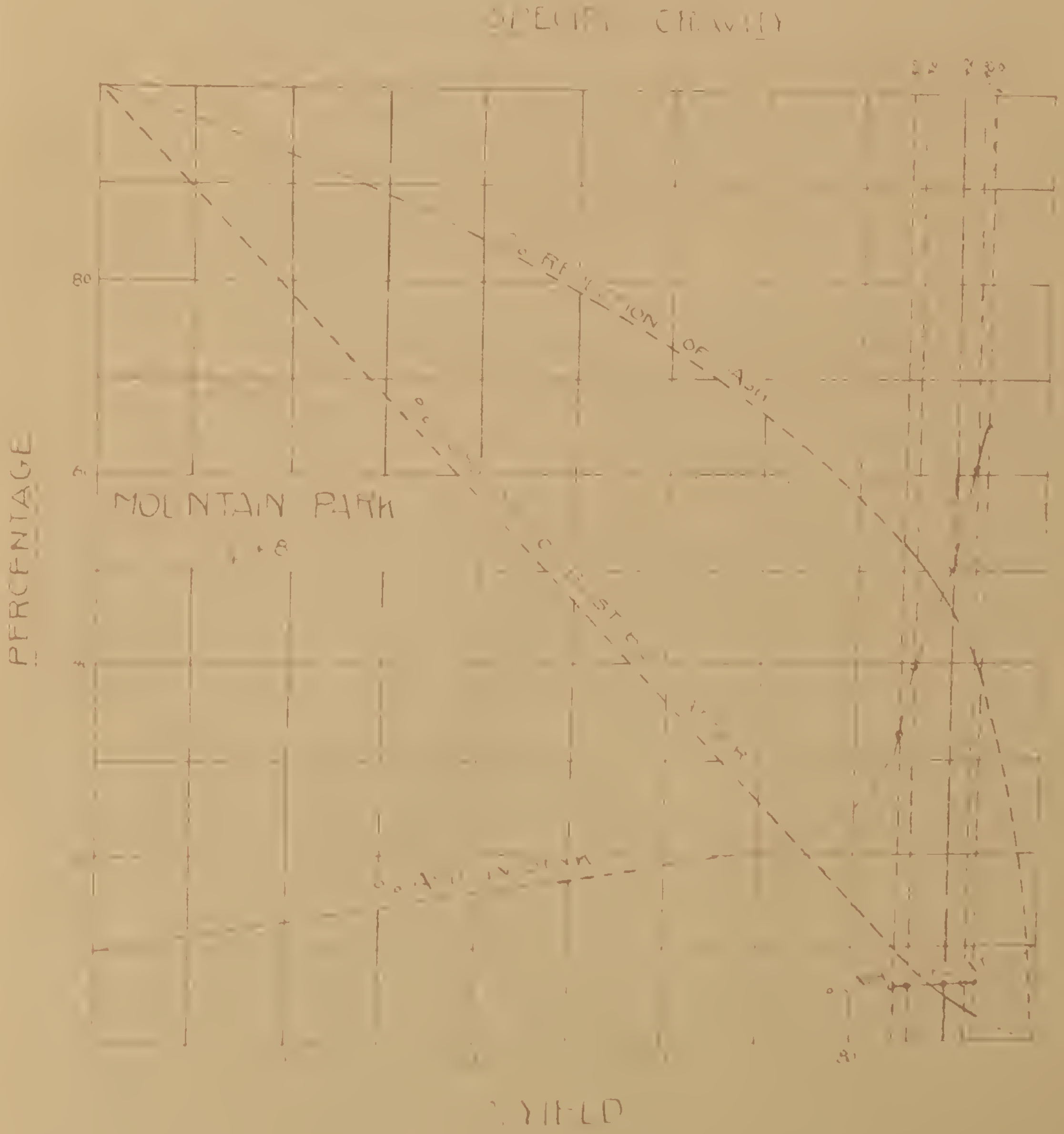

SPECIFIC GRAVITY
80
PERCENTAGE
MOUNTAIN PULP
8
2
4
% YIELD

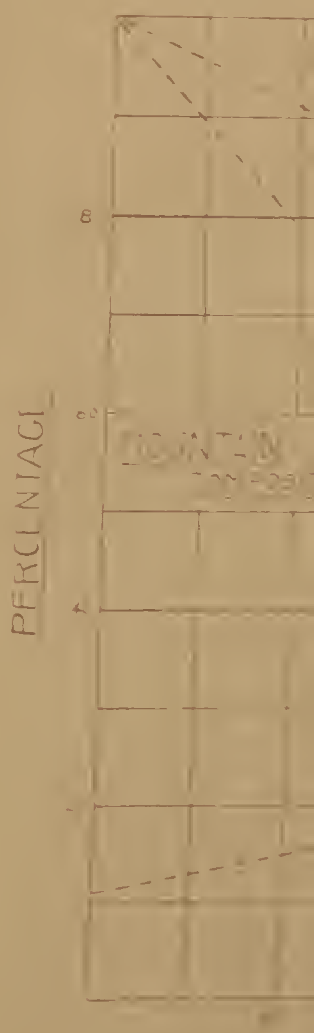

SPECIFIC GRAVITY
80

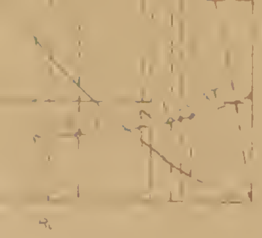

% ASH IN
% ASH IN FLOAT
20
40
60
80
% YIELD

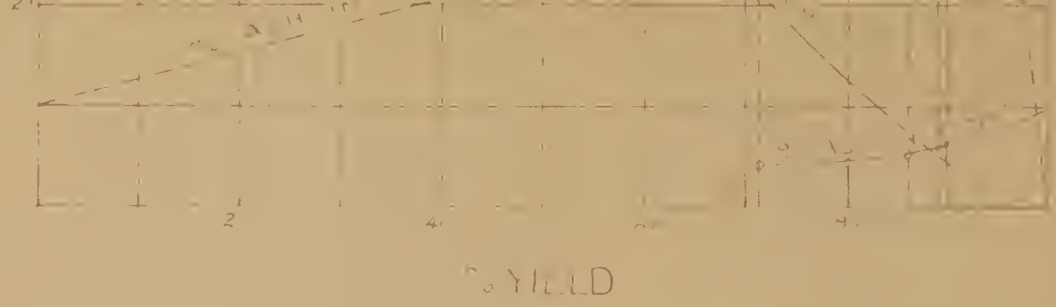

% YIELD


SPECIFIC GRAVITY
PERCENTAGE
MOUNTAIN PARK
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
40
% YIELD

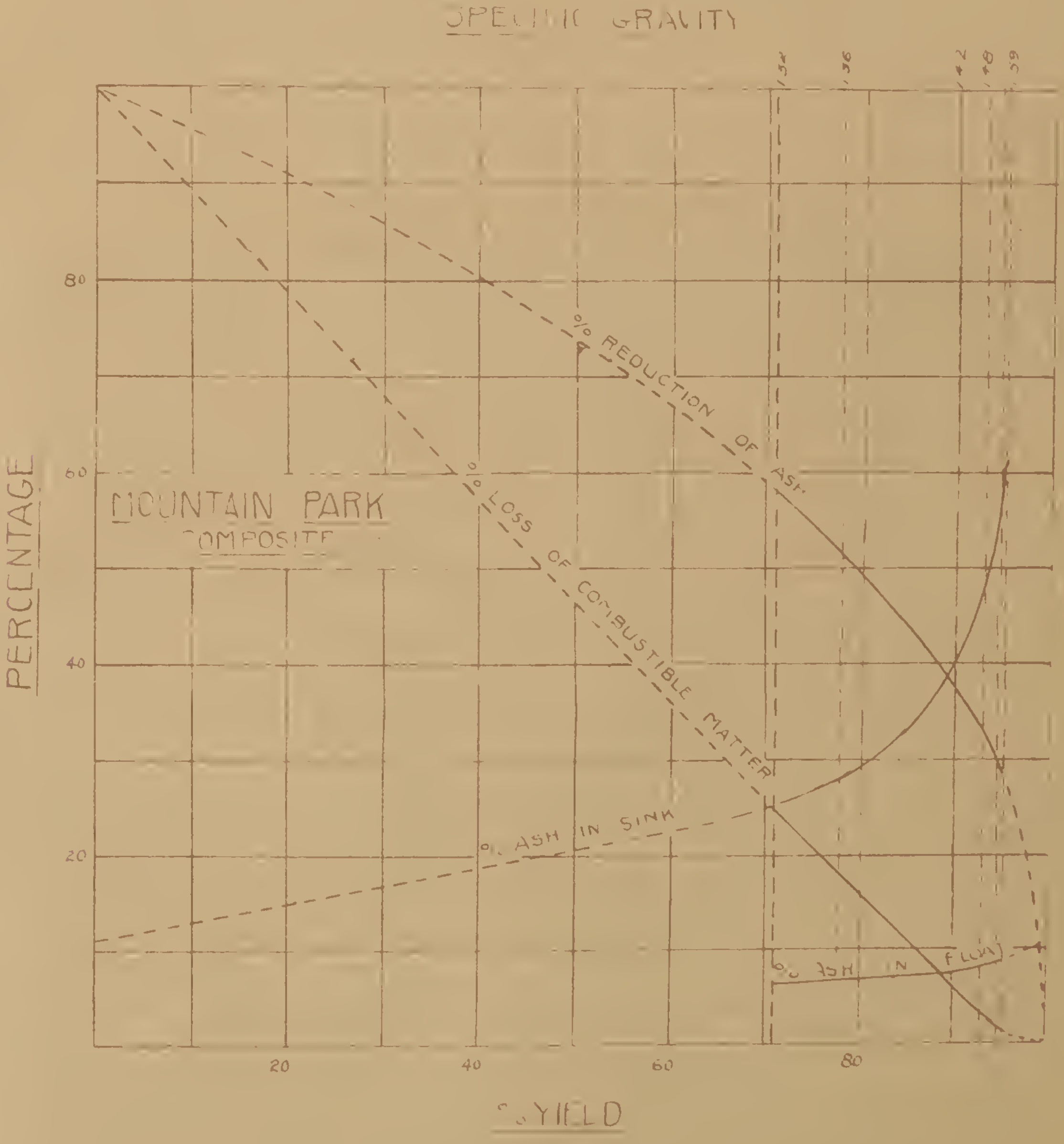

SPECIFIC GRAVITY
PERCENTAGE
MOUNTAIN PARK
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
80
% YIELD


PERCENTAGE
MOUNTAIN
8




% YIELD

% ASH

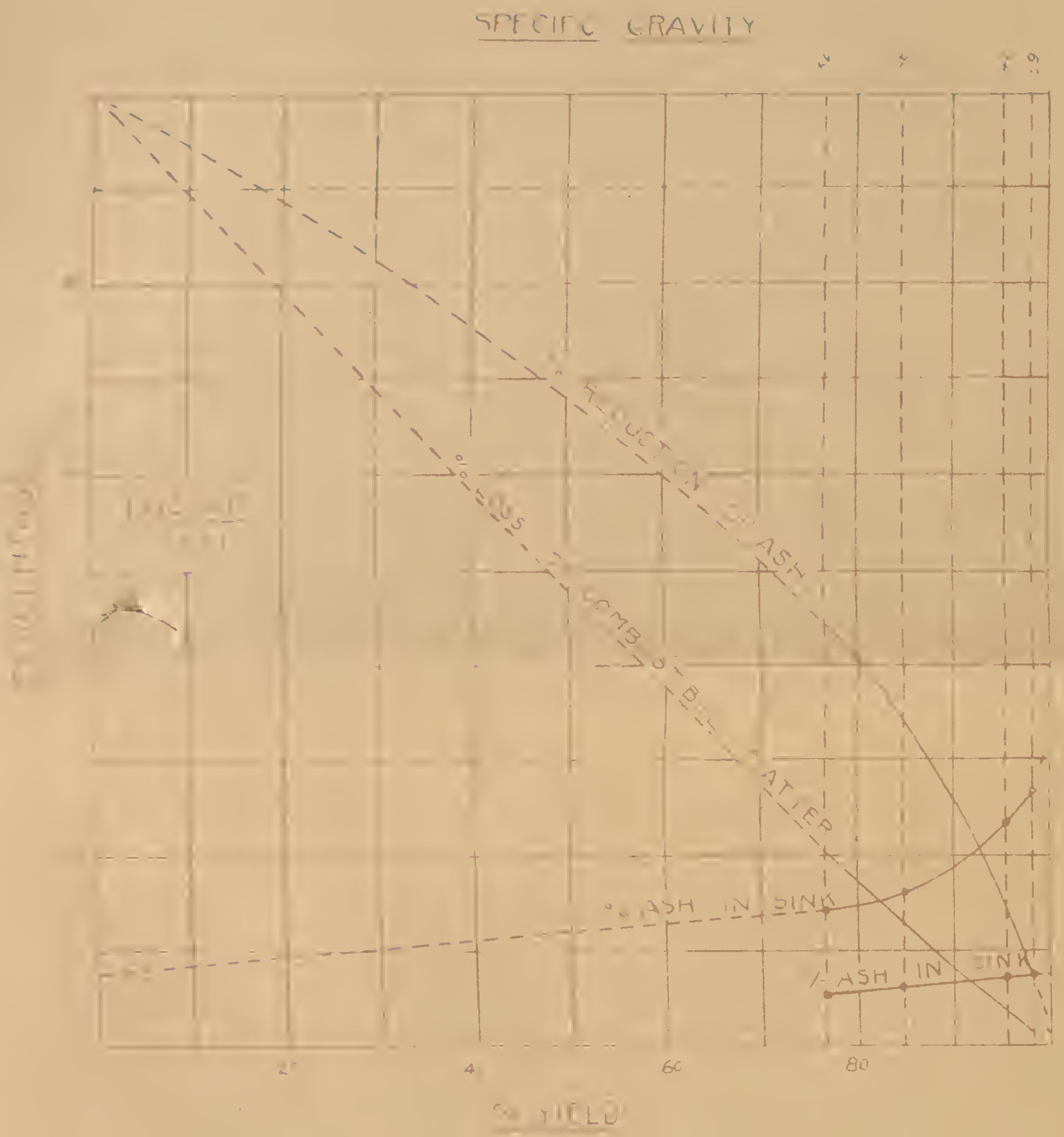

SPECIFIC GRAVITY
1.34
1.36
1.42
1.48
1.59
PERCENTAGE
80
60
40
20
MOUNTAIN PARK
COMPOSITE
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

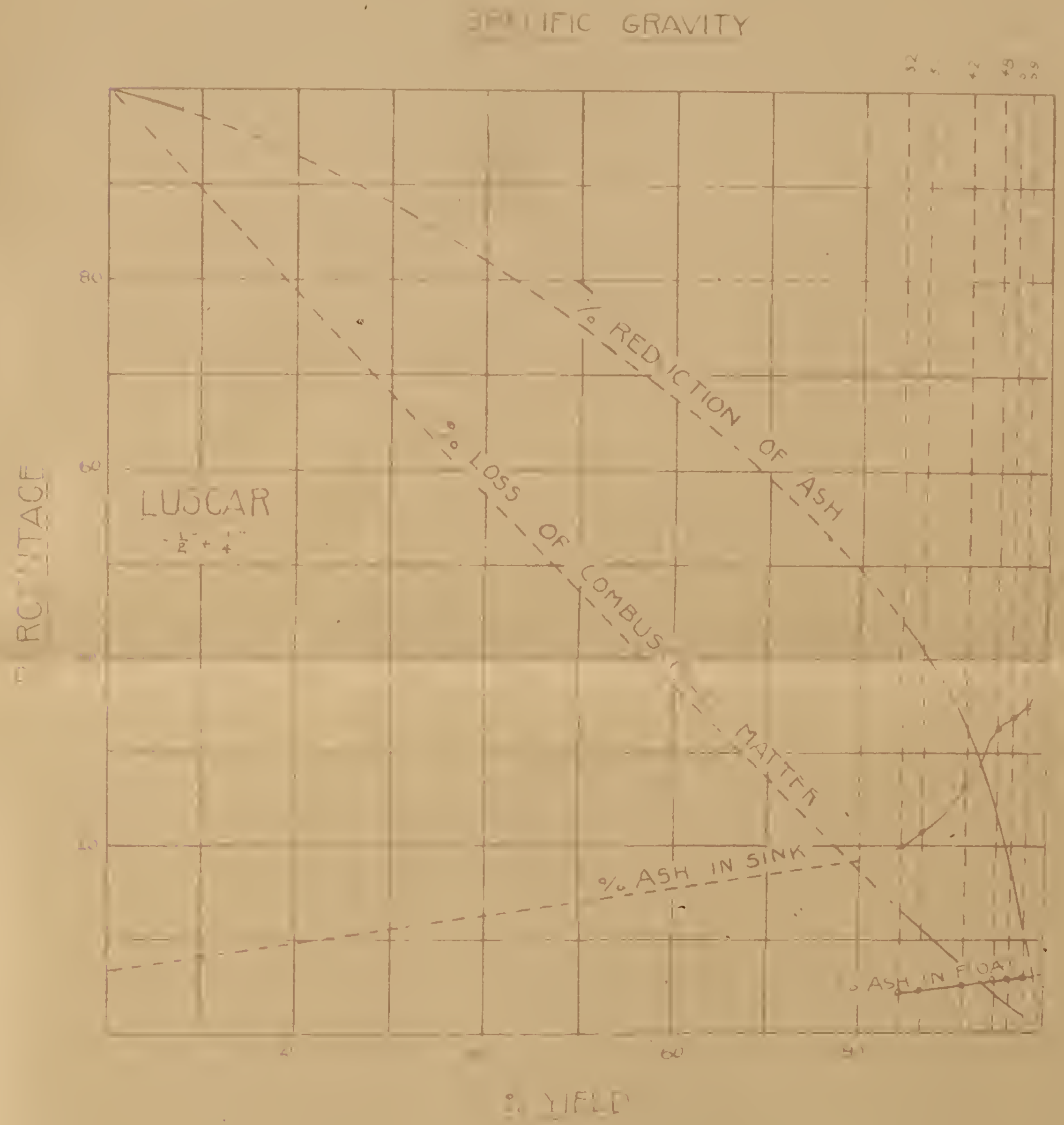
distinguished in the 1 to ½ inch size. The size greater than 1 inch diameter comprised about 33% of the sample, and the fines through 8 mesh about 20% of the sample (screen analysis, page 42). The coal was not as friable as that from Hillcrest or Brazeau. There was a decrease in percentage ash of the finer sizes as compared with the large, and in all sizes the percentage ash was low for uncleaned coal.

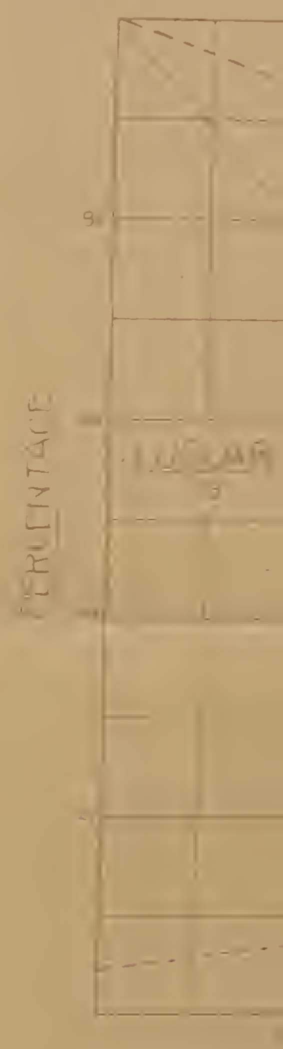
The float and sink tests were made by the unit method of procedure. This was particularly suited to this sample on account of the small quantity available. The specific gravity distribution of the composite (page 55) shows at least 93% is less than 1.42 specific gravity. The coal appears to be low in middlings as there is only about 5% of the material having a specific gravity between 1.42 and 1.59. Only 3 to 4% of the material is greater than 1.55 specific gravity. The specific gravity lines therefore occur close together at the points between 90 and 100% yield, which might be taken to indicate that efficient separations could be made within these limits.

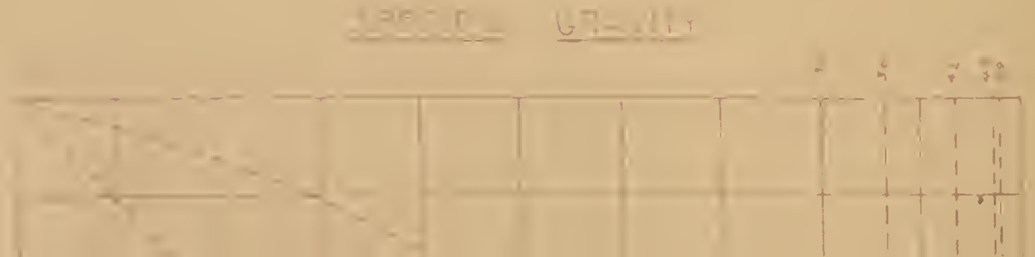
The composite curves for percentage reduction of ash and percentage loss of clean coal do not diverge as widely as in the Mountain Park sample, denoting that it is more difficult to reduce the impurities, probably on account of the already low percentage ash in the run of mine sample. At 90% recovery there is cleaned product with 6% ash, a loss of combustible matter of about 8%, and an ash reduction of 30%. These figures are less satisfactory than those for the previously described coals.

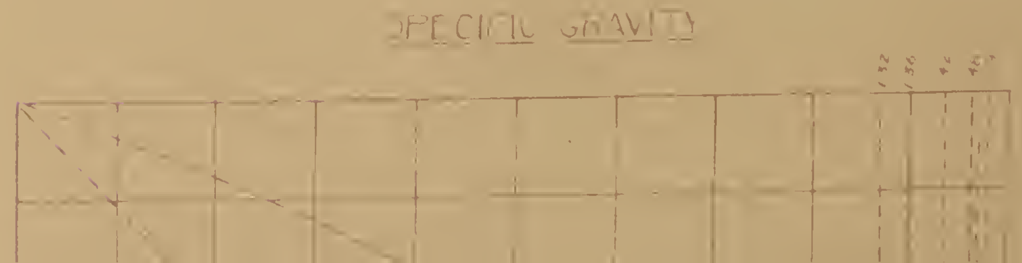
When the washability curves for the various sizes are considered, it is seen that the 1 inch size at any yield shows the least percentage ash reduction. The specific gravity distribution of this size is also wider than

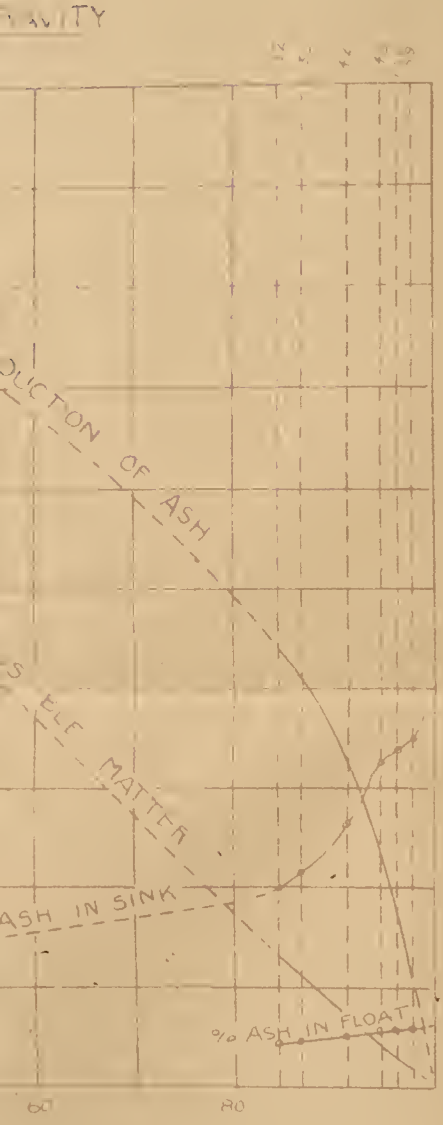

SPECIFIC GRAVITY
1.9
PERCENTAGE
LUSCAR
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN SINK
20
40
60
80
% YIELD

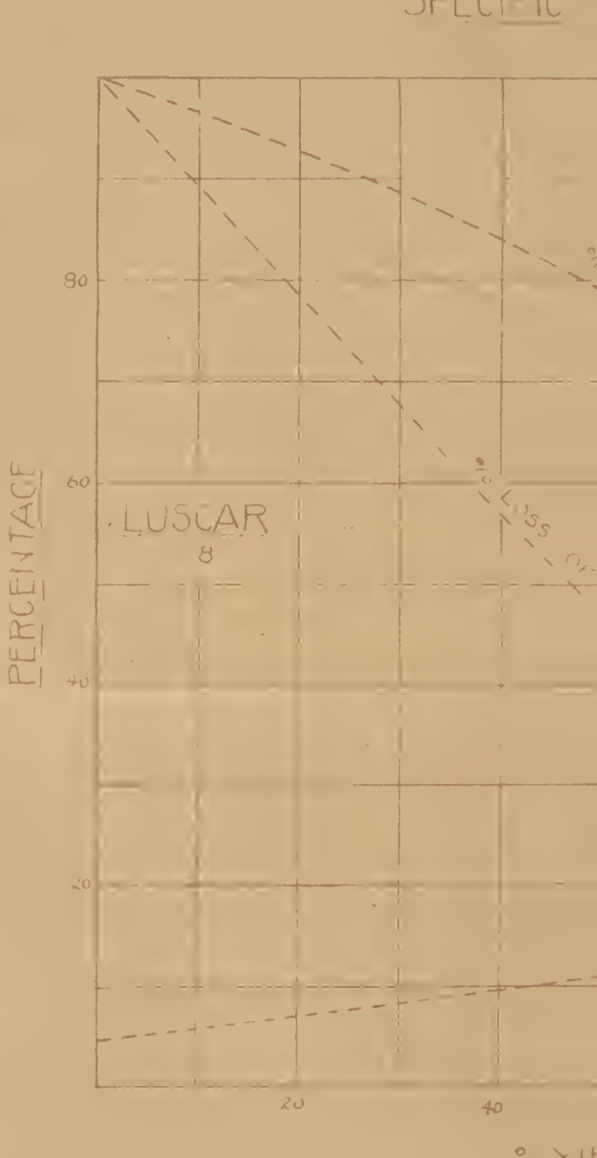

SPECIFIC GRAVITY
80
60
PERCENTAGE
LUSCAR
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

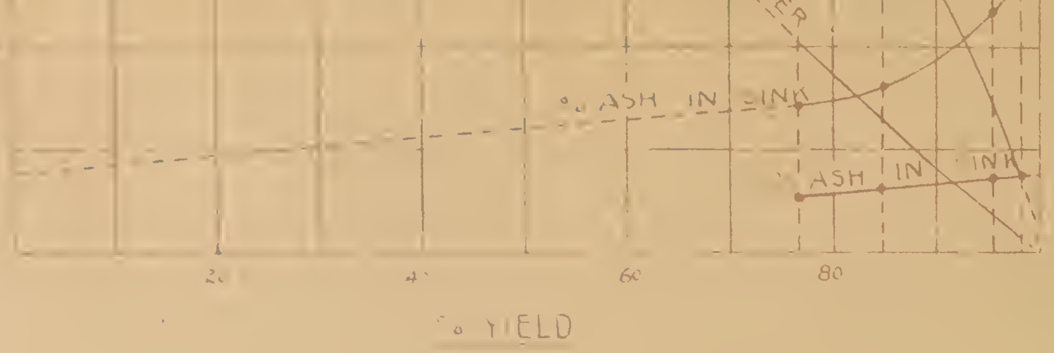

PERCENTAGE
LUSCAR

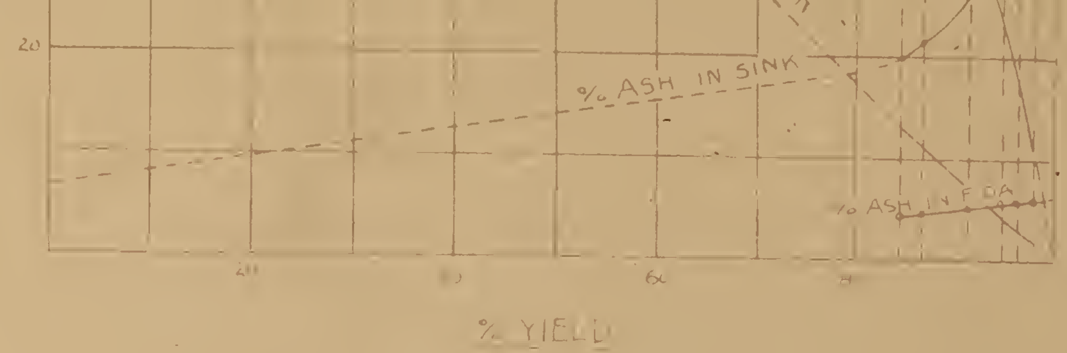

SPECIFIC GRAVITY

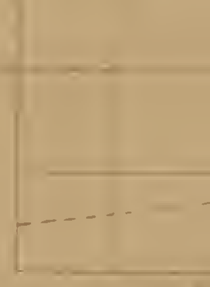

SPECIFIC GRAVITY

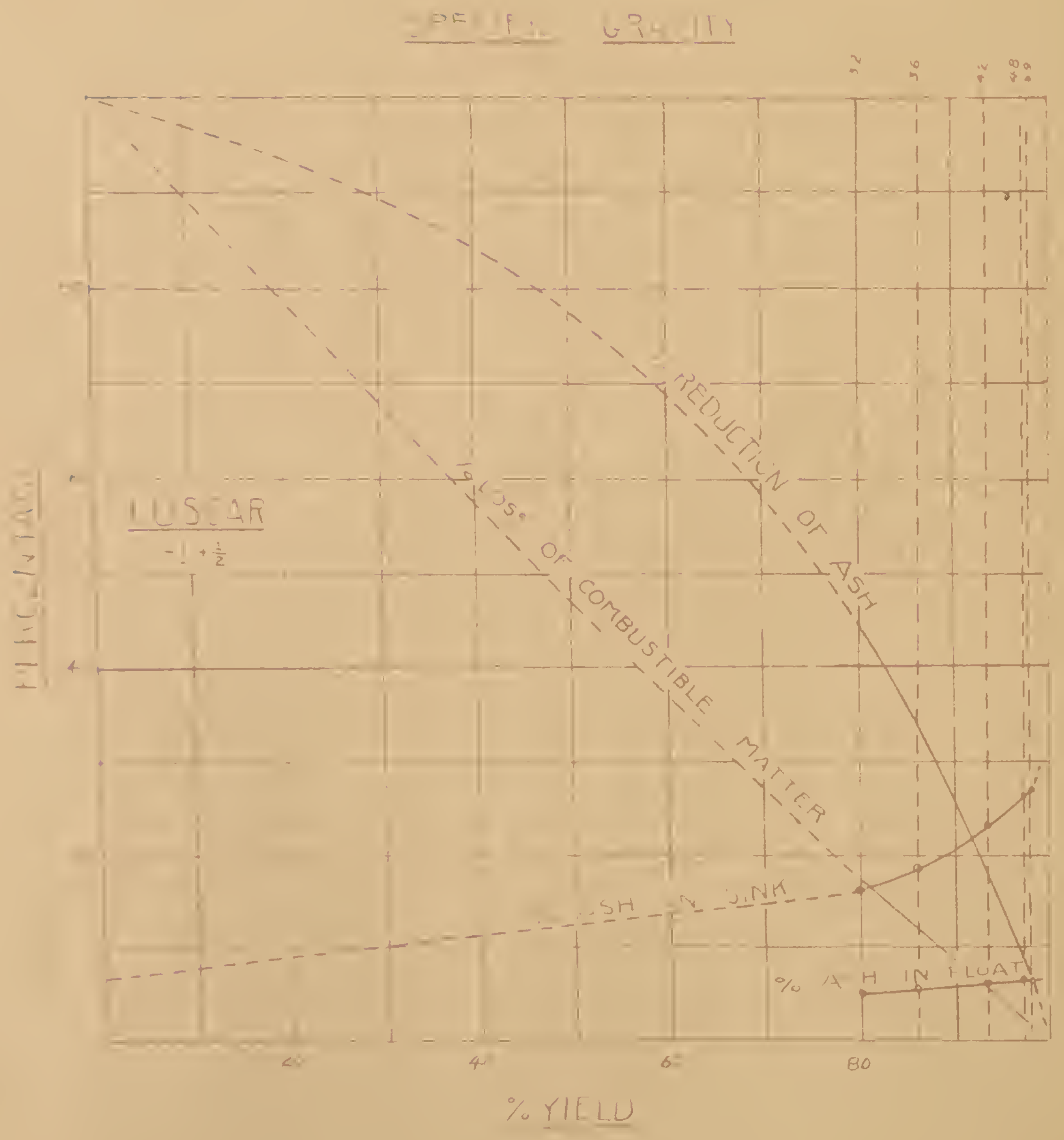

AVITY
UCTION OF ASH
S BLE MATTER
ASH IN SINK
% ASH IN FLOAT
60
80

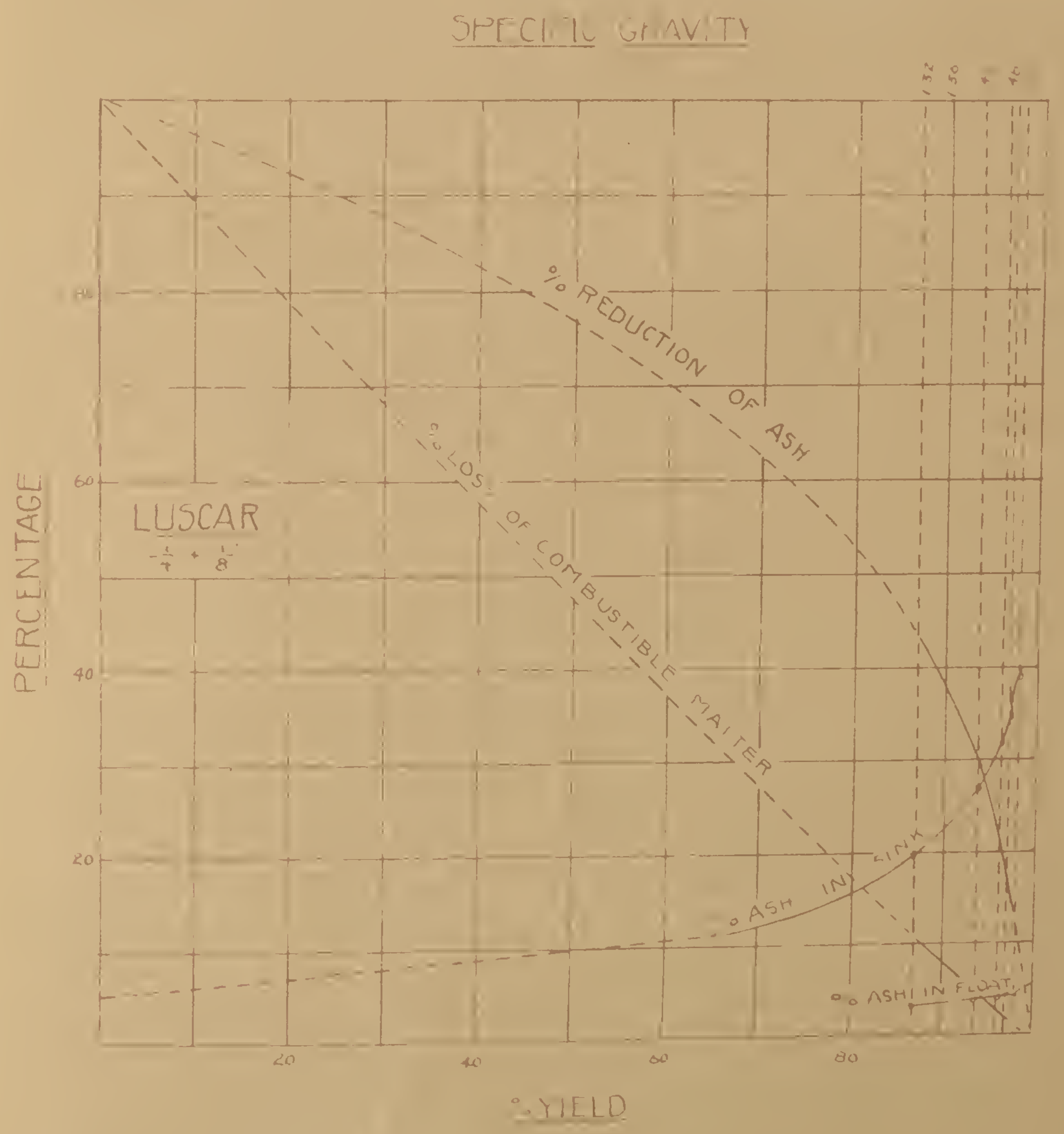

SPECIFIC
PERCENTAGE
80
60
40
20
LUSCAR
8
% LOSS OF
20
40
% YI


% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

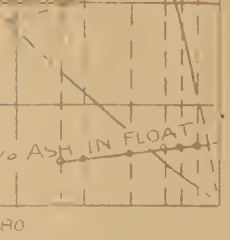

20
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD



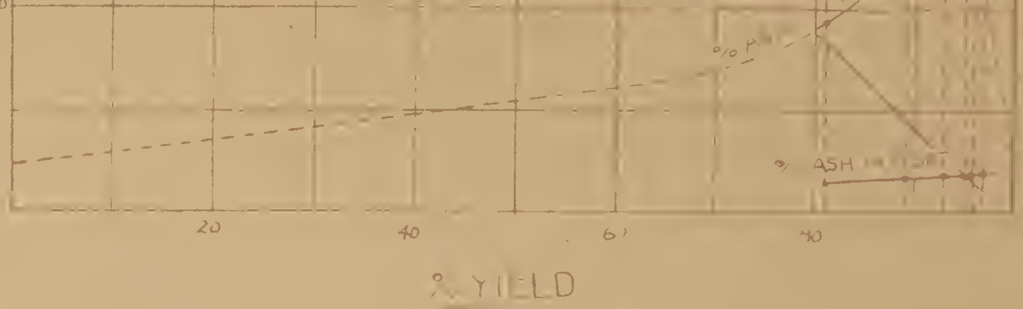

SPECIFIC GRAVITY
PERCENTAGE
LUSCAR
-1 + 1/2
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

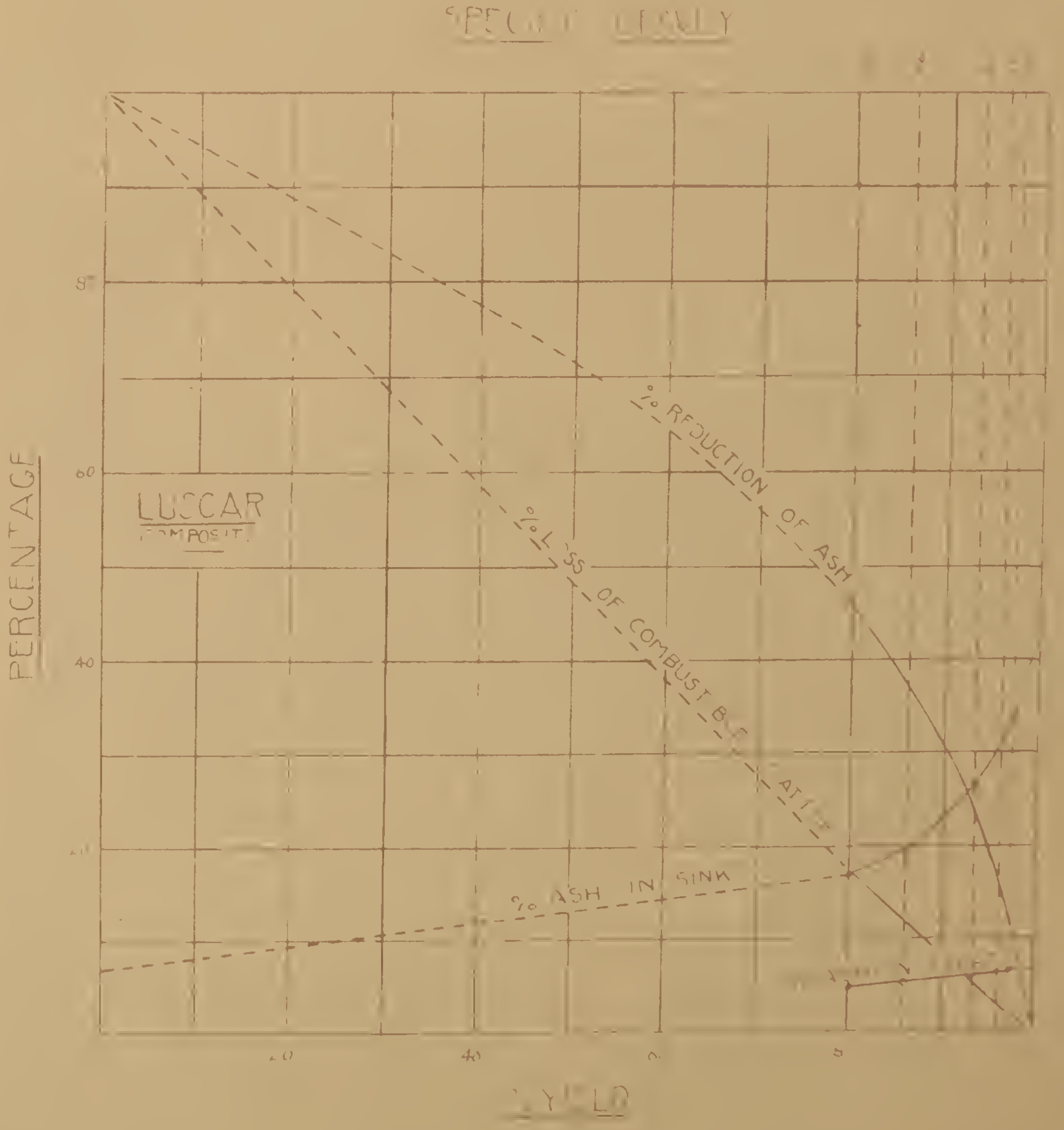

SPECIFIC GRAVITY
PERCENTAGE
LUSCAR
-1/4 + 1/8
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
20
40
60
80
% YIELD

PERCENTAGE
LUSCAR


% ASH IN FLOAT
80

1.32
1.36
1.42
1.60
SINK
% ASH IN FLOAT
80


20
% ASH
% ASH IN FLOAT
20
40
60
80
% YIELD


SPECIFIC GRAVITY
80
60
40
20
PERCENTAGE
LUSCAR
COMPOSITE
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

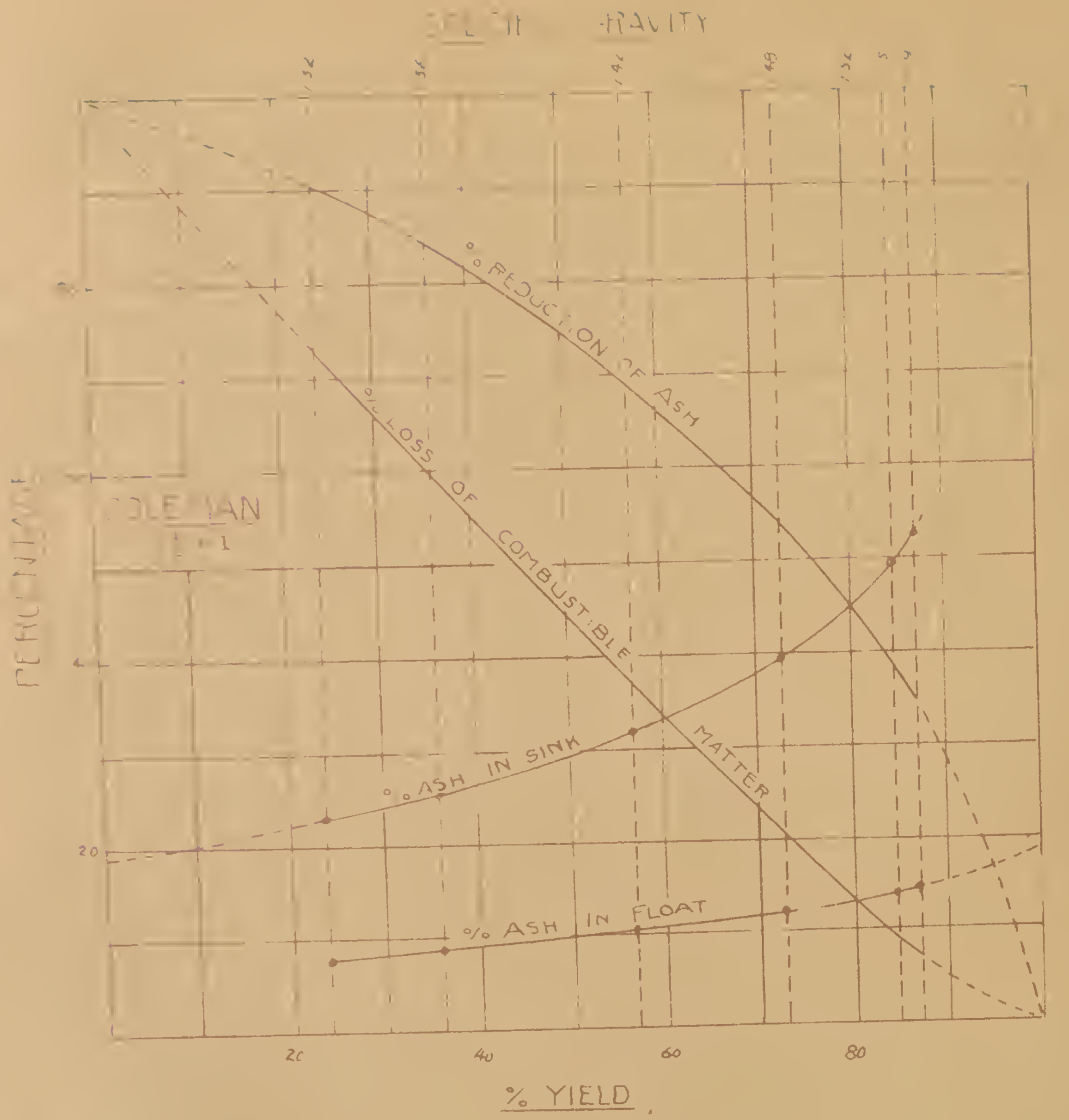
in the other sizes indicating a greater proportion of middlings. The ash reduction and loss of combustible matter curves tend to become farther apart in the smaller sizes, showing that a more efficient separation of the impurities takes place. In this characteristic the sample resembles that of Mountain Park. Discussion of the curves for this coal is unsatisfactory as the ash content of the sample tested was so low that there would be no question of commercial cleaning.

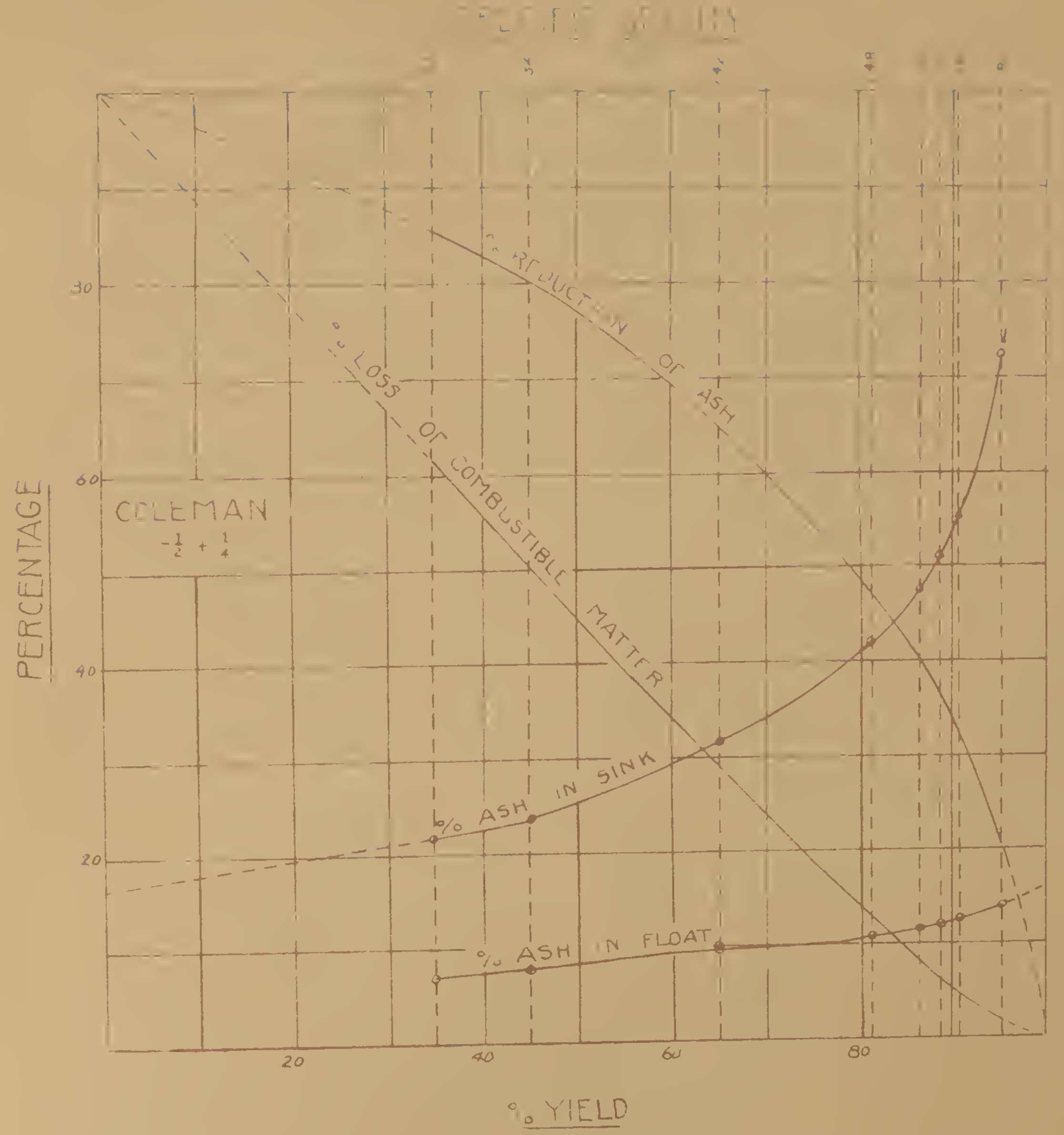
Section IV. Coleman. This sample was considered to be representative of the ordinary run of mine coal for the mine. The visible impurities appeared as pieces of dark shale much harder than the coal. Small patches of pyrites were seen on a few of the coal particles. The general shape of the coal tended toward flatness and particles of this shape predominated in the material whose specific gravity was greater than 1.55.

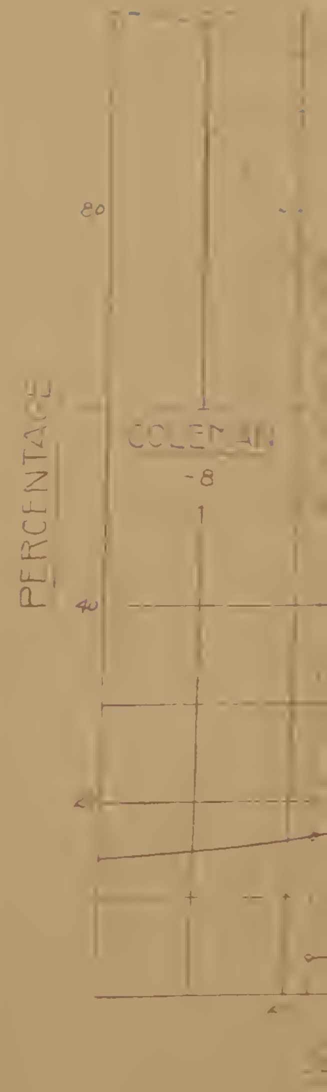
The screen analysis, page 42, indicated that the coal contained about 35% fines passing the 8 mesh screen. The percentage of ash in each size decreased from 19% in the largest size to about 15% in the fines, showing that the impurities were apparently less friable than the coal.

The average specific gravity distribution as shown by the composite curves, page 57, indicates that 63% of the material is lighter than 1.42 specific gravity, 24% between 1.42 and 1.55 specific gravity, and 12% greater than 1.55 specific gravity. The range appears to be wide with a large proportion of middlings. The advantageous points of separation would appear to lie between 85 and 90% recovery. The curves indicate that at 87% recovery, corresponding to 1.55 specific gravity, there is a cleaned coal with 11% ash, a 6% loss of combustible matter, a 38% reduction of ash, and a discard with 52% ash.

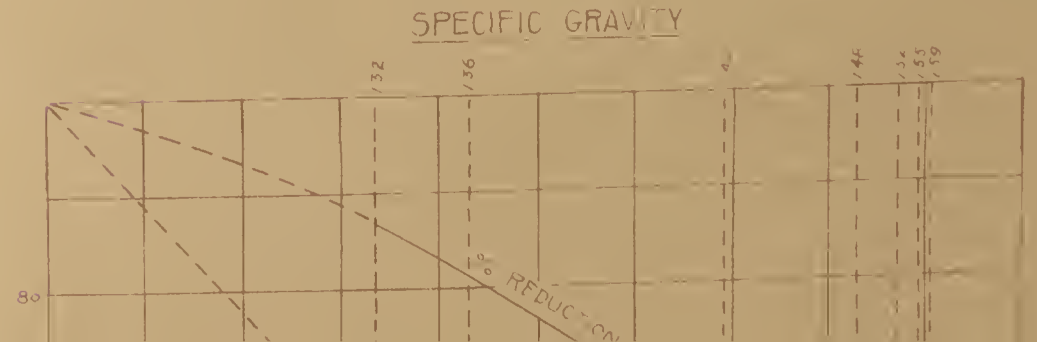
The percentage loss of combustible matter is about the same for all

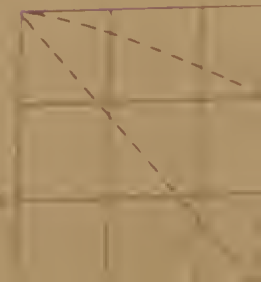

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
PERCENTAGE
COLEMAN
20
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

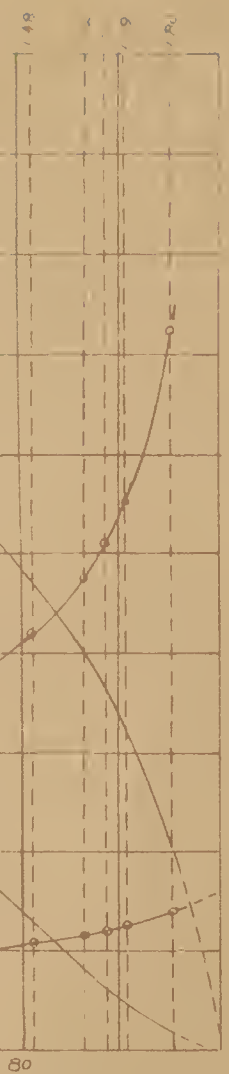

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
80
60
40
20
PERCENTAGE
COLEMAN
$-\frac{1}{2}+\frac{1}{4}$
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

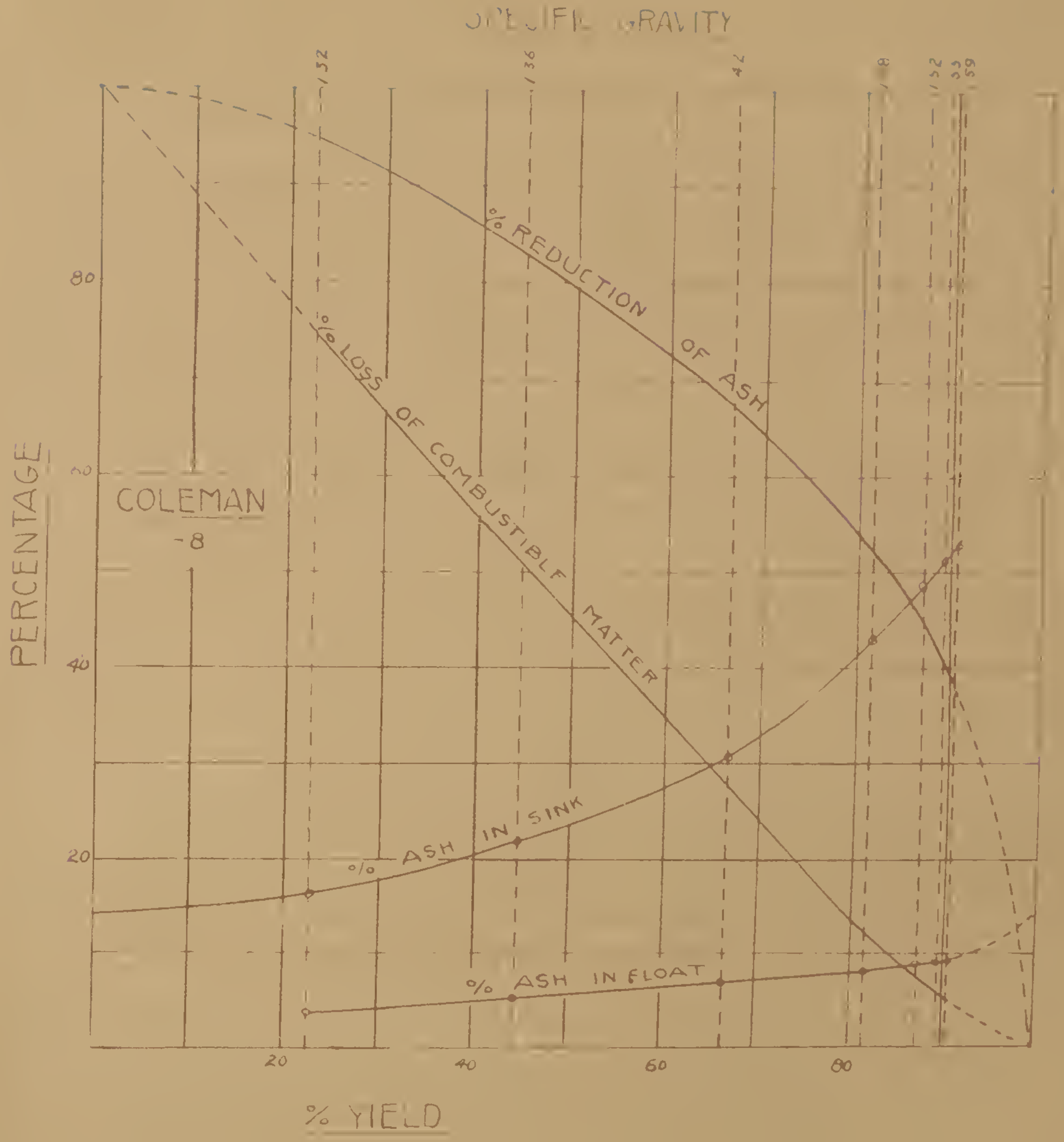

80
PERCENTAGE
COLEMAN
-8
40

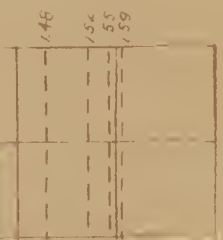
SPECIFIC GRAVITY
1.4
1.48
1.52
1.55


SPECIFIC GRAVITY
1.32
1.36
1.44
80
% REDUCTION

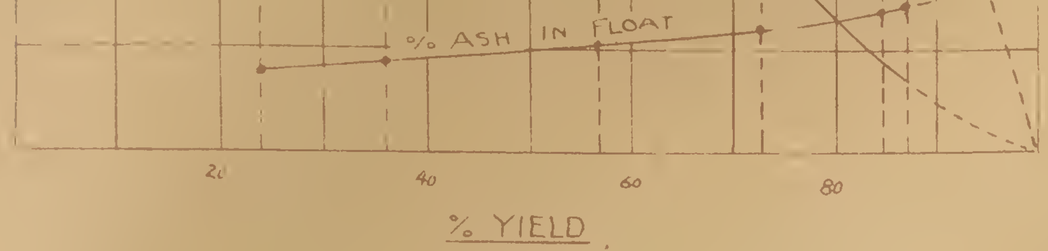


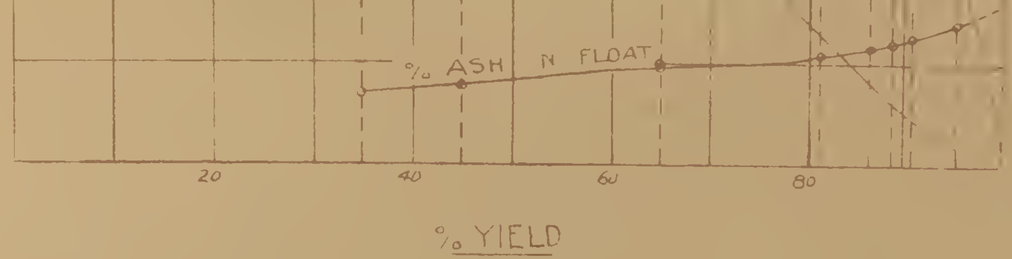


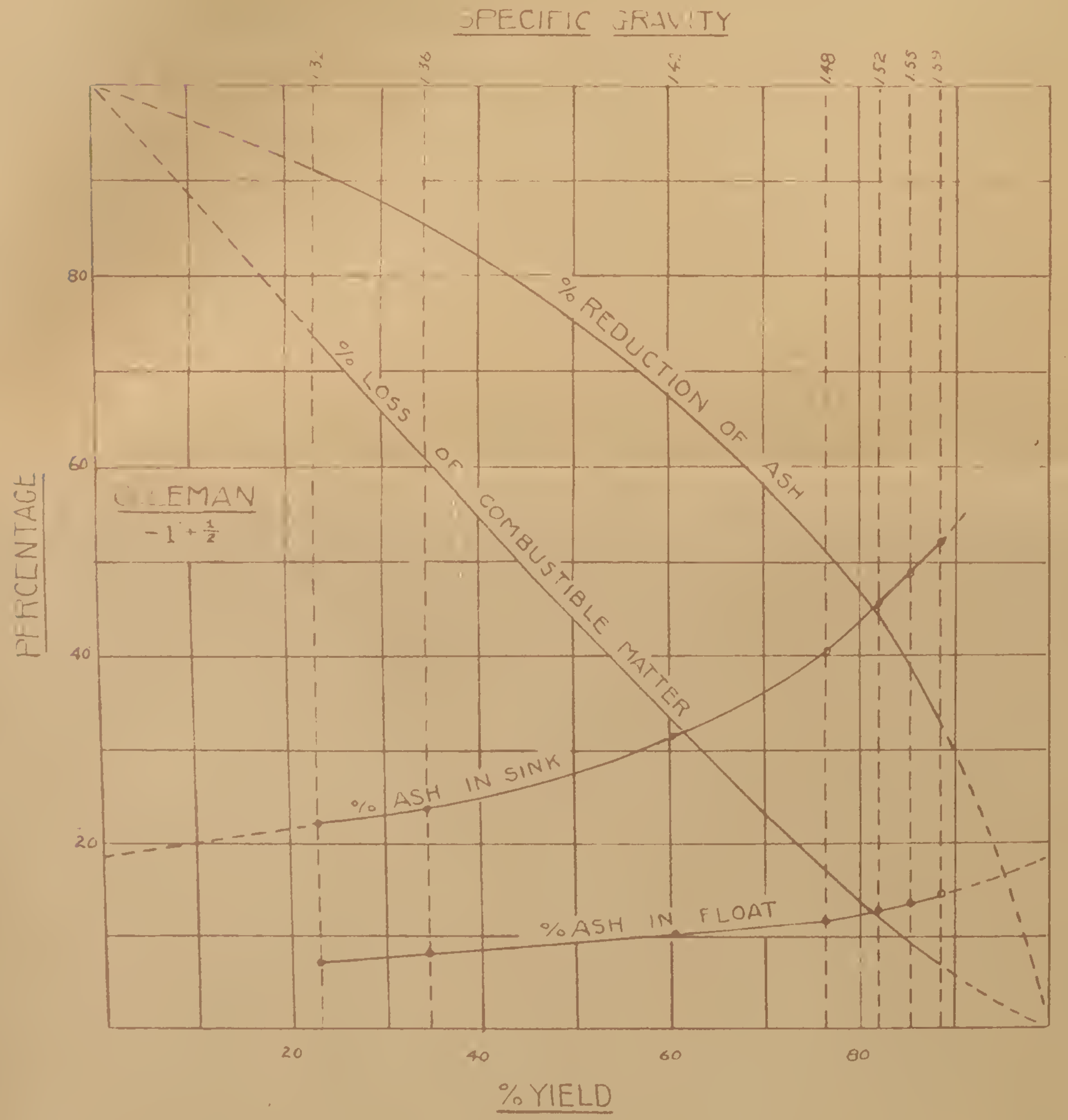

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
PERCENTAGE
COLEMAN
-8
80
60
40
20
20
40
60
80
% YIELD

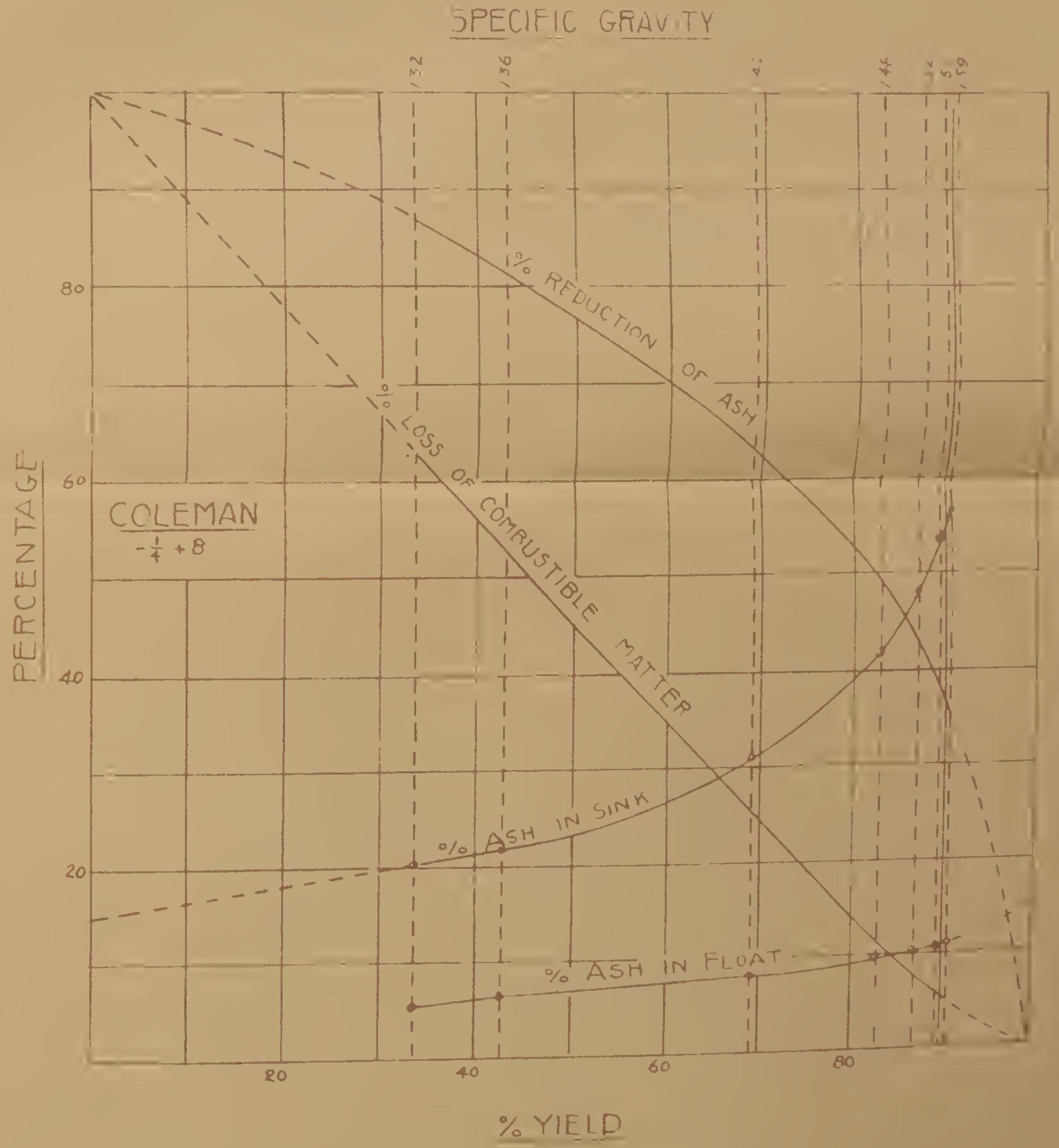


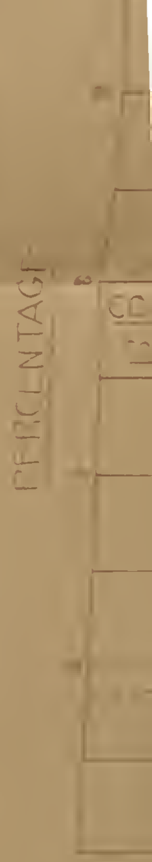
SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
80

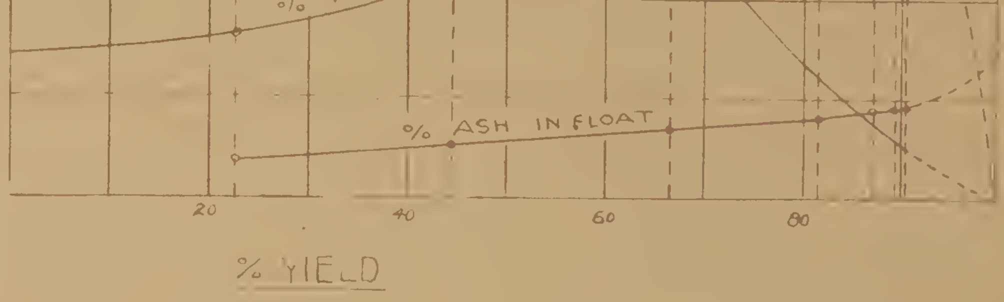

% ASH IN FLOAT
20
40
60
80
% YIELD


% ASH IN FLOAT
20
40
60
80
% YIELD

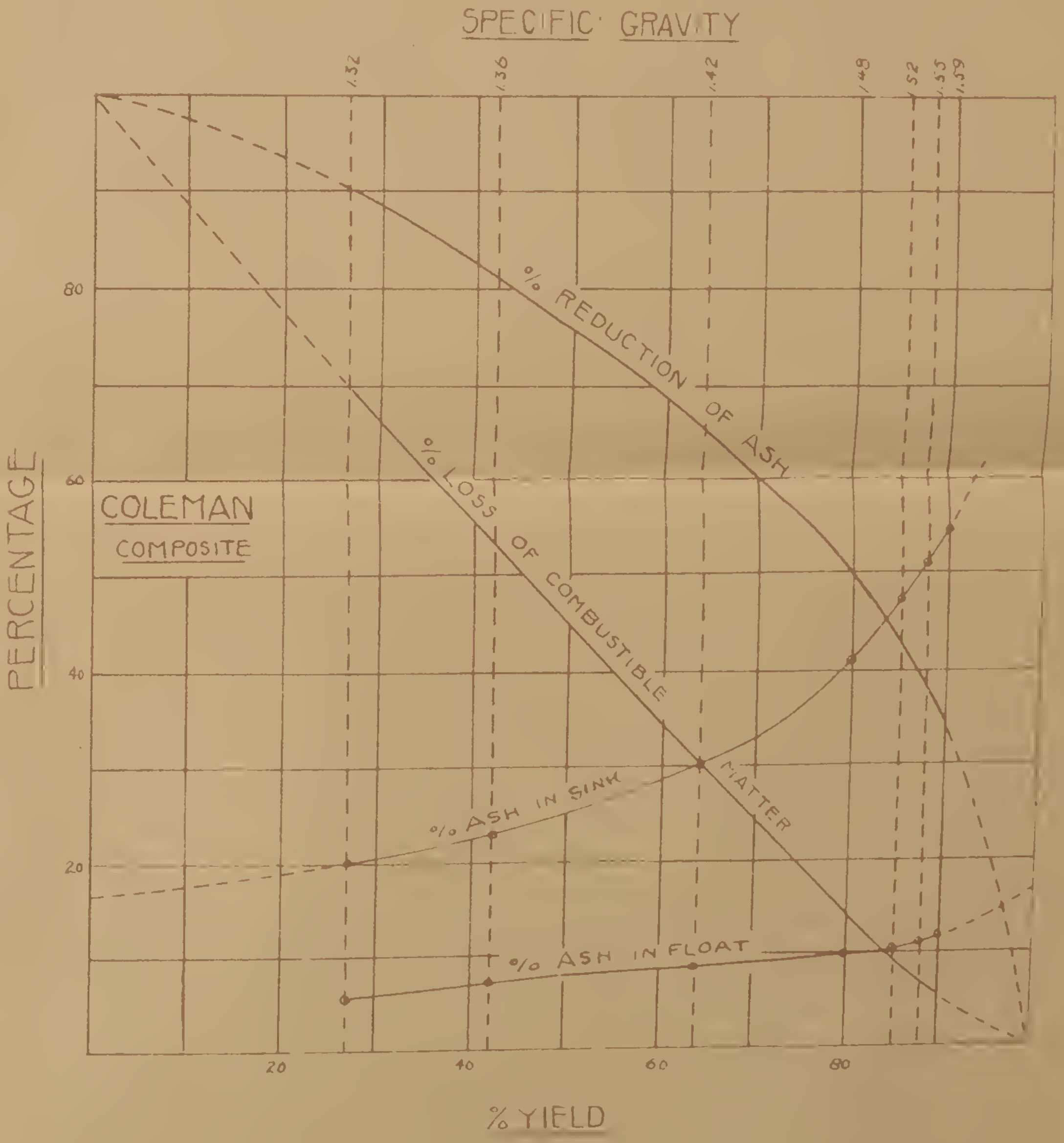

SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
PERCENTAGE
80
60
40
20
COLEMAN
-1 + 1/2
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD


SPECIFIC GRAVITY
1.32
1.36
1.42
1.44
1.5
1.59
PERCENTAGE
80
60
40
20
COLEMAN
-1/4 + 8
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD


PERCENTAGE


%
% ASH IN FLOAT
20
40
60
80
% YIELD

.55
.59


SPECIFIC GRAVITY
1.32
1.36
1.42
1.48
1.52
1.55
1.59
80
60
40
20
PERCENTAGE
COLEMAN
COMPOSITE
% REDUCTION OF ASH
% LOSS OF COMBUSTIBLE MATTER
% ASH IN SINK
% ASH IN FLOAT
20
40
60
80
% YIELD

the sizes, but the percentage of ash reduction tends to increase with decreasing size despite the greater amount of impurities in the larger sizes.

The material greater than 1.59 specific gravity, for size $\frac{1}{2}$" to $\frac{1}{4}$", was further separated at 1.80 specific gravity. The figures obtained did not alter the curve from the line it would have followed above 1.59 sp. gr. if it had been drawn by interpolation as were all the other curves.

The washability curves discussed tend to show that a distinct ash reduction might be obtained with small loss of combustible matter. A washery might clean this coal by making a three-product yield of clean coal, middlings and discard. About 64% cleaned coal could then be recovered with an ash of 8%; 21% middlings, with an ash content of 21%, might be disposed of locally; and the remaining 15% with an ash content of 54% would be discarded as useless. By-passing the fines and recombining with the other cleaned sizes would not permit of a material reduction in the total ash since the fines compose 36% of the raw coal and contain at least 15% ash. A three-product yield might also be made for Brazeau and Hillcrest.

General Comparison of Washability.

The commercial results of all the washability tests have been summarized in the following table on the assumptions: - that really clean coal is that with less than 1.42 specific gravity, that middlings have a gravity between 1.42 and 1.55, and that the really clean coal and the middlings can be combined as marketable coal. It must be recognized, however, that no attempt can be made in more than a general way to compare the washability of these coals unless the numerous local conditions which decide the points of separation are known. Furthermore, as already stated, the middlings may be disposed of locally.

TABULATION OF COMMERCIAL WASHABILITY DATA.

Sample	Yields				Ash Contents			Reduction of Ash	Loss of Combustible Matter
	Clean Coal %	Middlings %	Marketable Coal %	Discard %	Raw Coal %	Marketable Coal %	Discard %	%	%
Hillcrest, -$\frac{1}{2}$" +$\frac{1}{4}$"	60	20	80	20	17.83	8.0	64.0	63	10
Brazeau #2 Composite	68	18	86	14	15.13	9.5	43.5	44	9
Coalspur, -$\frac{1}{2}$" + $\frac{1}{4}$"	63	15	78	22	21.18	10.5	59.2	63	10
Mountain Park, Comp.	90	5	95	5	11.00	8.1	57.5	29	2
Luscar, "	93	4	97	3	6.68	6.0	32.3	13	2
Coleman	64	24	88	12	16.09	11.3	50.9	38	6

CHAPTER VIII.

THE DEWATERING OF COAL BY DRAINAGE AND ITS RELATION TO FREEZING.

Winter temperature conditions in Alberta with the consequent possibility of the wet products of the washery freezing in storage or during shipment have been assumed to practically prohibit the operation of wet washeries. Vissac[17] has stated that in Alberta sizes from 3/4 to 2 inches are the only ones which can be so treated, because it is possible to drain these coals before shipment. The drainage of small sizes is too difficult and expensive. A wet washery at Corbin, B. C. has shown that though it is possible to operate with more or less difficulty under low temperature conditions, trouble is encountered in the freezing of the wet washed coal, particularly when shipped some distance. It was therefore felt that some investigation on the relation between the moisture content of wet washed coal and atmospheric temperatures of lower than the freezing point would yield information of value.

Little work appears to have been done on this subject. An attempt was made by E. L. Jones[5] in 1923 for the Research Council Laboratories, but his results were inconclusive. They did, however, point to the fact that evaporation of excess water as well as drainage had to be taken into consideration.

Mott[4] has stated that in bituminous coals, water may be either inherent or adventitious. He calls inherent water that which remains after air drying, and states that it is likely to be present as an adsorbed layer on small particles. He places the inherent water content of coals in Great Britain at from 1 to 10%. If inherent water is assumed as defined above,

numerous analyses of Alberta coals[8] have shown a variation of from 1.5 to 37.5% moisture as mined, depending on the age of the coal and the horizon from which it was obtained. Inherent water is independent of the size of coal particle. Its chief effect as far as the commercial use of coal is concerned, is its effect in lowering the calorific value of the coal.

Adventitious water is that which may be introduced from the mining or washing of the coal. The moisture retained in a coal depends upon the amount of space between the coal particles and the relation of the space to the surface area of the coal and the power surface tension thereby involved. If the spaces are large, the water tends to drain away, while if the interstices are small, the water is held in place by surface tension.

Chapman and Mott show that drainage may be of three kinds; (a) natural drainage, (b) forced drainage, (c) centrifuging. They show that natural drainage occurs when the force of gravity exceeds the force of surface tension; that forced drainage takes place when the coal is jigged about or agitated in a container, the agitation apparently tending to disturb the forces of surface tension and free the coal of adventitious moisture. They experimented with these various methods of drainage and found that by agitation or jigging the interstitial space in sized coal may be reduced from 57% of the volume, the normal amount, to about 47%, and that the amount of water held in these spaces may represent only 40% of the volume. The authors conclude that such mechanical processes may be used to reduce the adventitious water content of coarsely sized coal to a certain limit, but for further reduction, the water must be removed by evaporation under the application of heat.

Working with closely sized coals at sizes below 1/100 inch, they

showed that the amount of adventitious moisture retained is practically a constant equivalent to 50% of the volume and state that if the amount of water retained finely divided, unsized coal is dependent mainly upon the percentage of material which is less than 1/10 inch diameter.

Present Investigations.

Natural drainage only was considered for the purpose of the investigation about to be described, because an absolute result was desired rather than a comparison of moisture removal by different methods.

The drainage tests were carried out for a sample of coal from Brazeau, though it was found later that the friability of this sample was an objectionable feature. The sizes used were; run of mine, 1½ to 1 inch, ½ to ¼ inch, ¼ inch to 8 mesh and through 8 mesh (Standard Screens). The containers were gallon tins holding about a kilogramme of coal each and having holes punched along half the edge of the base for drainage. A piece of cloth was placed over a number of wires in the bottom of the tin to retain the coal and create channels for the passage of the water. It was also apparent that there would be a considerable loss of moisture from evaporation over a considerable length of time, and to prevent this effect the tin was covered with a tightly fitting lid having a very small hole to equalize the atmospheric pressure above and below the coal. A rack was made to hold the tins at an angle of about 60 degrees from the horizontal.

The tin containing the kilogramme of coal was immersed in water for about two hours to allow the interstitial space to fill with water. The weighings were taken after an initial period of fifteen minutes drainage and then repeated for each tin at regular intervals. A graph showing the relation between percentage of moisture and time is shown on the following page.

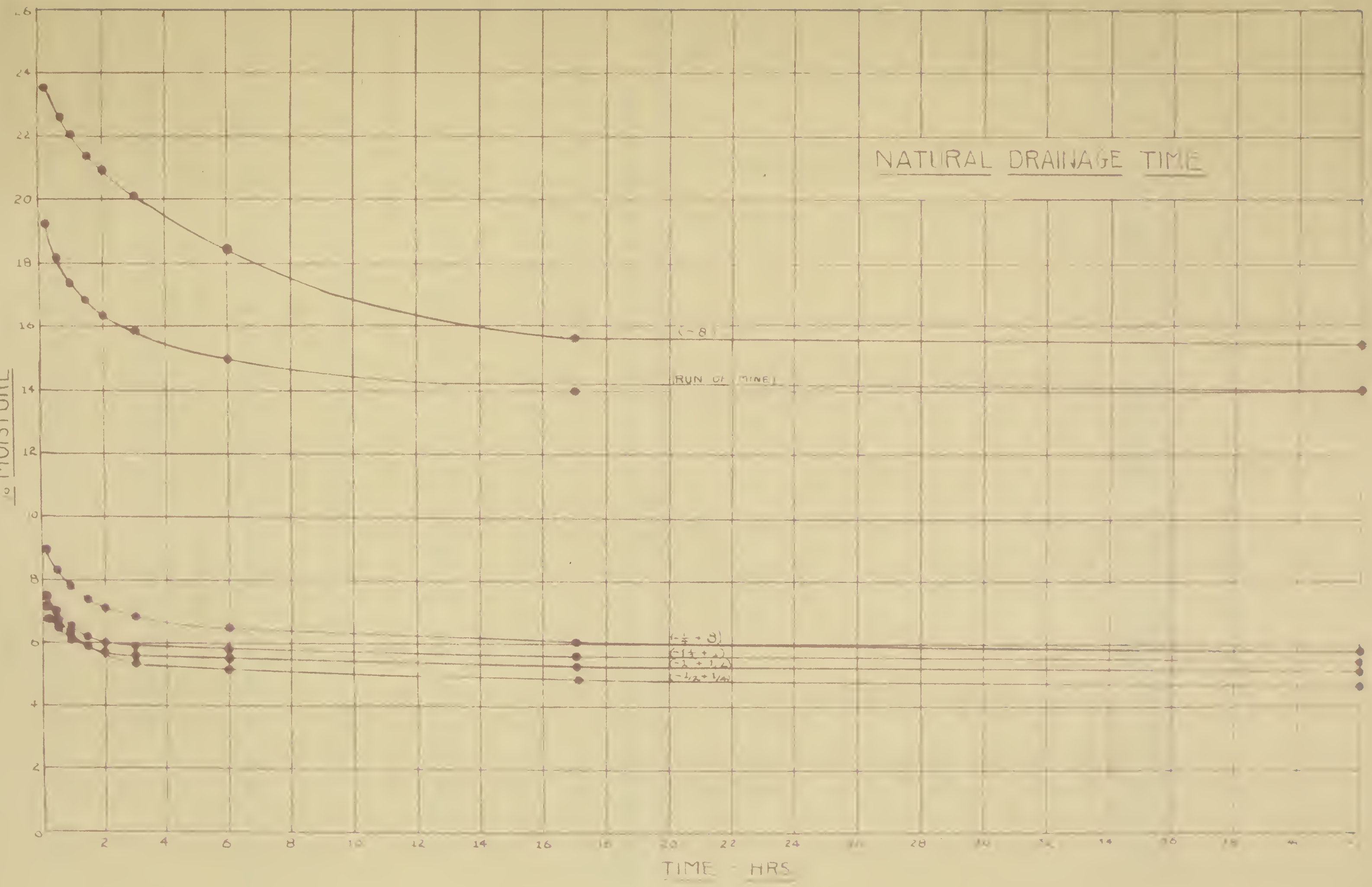

NATURAL DRAINAGE TIME
(-8)
(RUN OF MINE)
(-¼ + 8)
(-1½ + ½)
(-1 + ½)
(-½ + ¼)
% MOISTURE
0
2
4
6
8
10
12
14
16
18
20
22
24
26
TIME - HRS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
36

FIGURE XI.

The following drainage results were obtained by Mott:

Size (Mesh I.M.M.)	% of Water in wet coal after drainage for: -			
	5 min.	1½ hours	3 hours	20 hours
5 - 10	22	20.5	19.5	19.5
10 - 20	38	36	35.5	35.5
20 - 40	45	43.5	42.5	41
40 - 60	46	44.5	43.5	42.5
60 - 90	50	48.5	47.5	47.5
90 - 120	46	44	44	43
120 - 150	46	44.5	43	43
150 - 200	46	45	44.5	44.5
- 200	46	44	43	43

The drainage curves as obtained in this experiment illustrate that the drainage in the various sizes takes place at a rapid rate at first, then gradually slows down so that a considerable length of time is required to cause an appreciable change in moisture content. The point of inflexion for size through 8 mesh is reached in from 14 to 18 hours, for the intermediate sizes in about 6 hours, and for the largest size in 1 hour. The points for each size indicates approximately the percentage of retained moisture.

The data secured by Mott in the above table indicates that his method was less effective, as far as drainage was concerned. He used a funnel covered with a watch glass as a container and various conditions may have prevented the greater degree of free drainage obtained in this experiment.

The Freezing of Wet Coal.

One of the principal disadvantages of handling wet coal in a cold climate is its tendency to freeze when exposed to temperatures below the

freezing point. This is particularly true when the freezing takes place in railway cars making difficult the removal of frozen material. It is therefore important that the moisture content be sufficiently low to prevent such a condition. Freezing tests were carried out on the sample of coal from Brazeau for which drainage results had been established to attempt to determine the maximum allowable moisture content for shipment in low temperatures.

A number of variable factors have to be considered in devising a test for this purpose. These are outlined below, together with the steps to be taken to minimize these effects.

(a) The degree of compactness of the particles. If the coal is in a loose condition, the friability of the frozen coal may be misleading. Conditions of storage in bins and cars seem to suggest that a fairly compact state is necessary if the results are to have practical significance.

(b) Drainage during the process of freezing. Unless very cold temperatures exist when the coal is being frozen, some drainage may take place if there is sufficient moisture present, and the lower layers of coal will be frozen more solidly than those at the top. The sample and container might be rotated during freezing to prevent drainage, but this is not similar to ordinary commercial practice. It has been assumed that natural drainage will take place in storage bins or hoppers over an appreciable length of time previous to shipment. Accordingly, freezing tests were made at percentages of moisture which the drainage results already established showed that there was little possibility of the layering effect developing.

(c) Evaporation and sublimation. The freezing tests were made with the moist coal enclosed in a wax paper container.

(d) Temperature. It is necessary that the freezing work be done as

quickly as possible in order to minimize the variability arising from the factors of drainage and evaporation. Most of the freezing tests in these experiments were made at temperatures below zero Fahrenheit.

(e) The degree of solidity of the frozen material. A crushing test is not suitable as a good deal of the crushing force will be resisted by the coal particles themselves, and the point of collapse may be characterized by the breaking of the coal particles rather than that of the film of frozen moisture. A kind of shatter was adopted in which the frozen material was dropped one or more times from a height of about six feet on to an iron plate. The estimation of the friability of many of the more loosely frozen samples could only be obtained by personal observation and judgment.

The containers used for the experiments were tins, cylindrical in shape about six inches in height and five inches in diameter. These were lined with wax paper so that when the moist coal was placed inside, the top edge of the paper could be folded over and fastened tightly to prevent evaporation. The paper lining the base of the tin was cut in strips and folded in with the side, allowing excess moisture to drain through and out of numerous holes punched in the bottom of the tins.

The freezing tests were made for six sizes as follows: run of mine, $1\frac{1}{2}$ to 1 inch, 1 to $\frac{1}{2}$ inch, $\frac{1}{2}$ to $\frac{1}{4}$ inch, $\frac{1}{4}$ inch to 8 mesh (T.S.S.), and through 8 mesh. One kilogramme of coal was used for each freezing determination. Samples of each size were frozen at different percentages of moisture content. The required moisture for each sample was calculated for air dried coal and water was then added to each sample in amounts necessary to raise the percentage of moisture to the desired figure. The water was poured over and stirred into the coal in the container at first, but it was found that poor

mixing resulted and that the coal so treated was not uniformly frozen throughout. The coal and water were then mixed in a porcelain lined tray, added to the container, and moderately packed with a spoon.

When the mixture had been frozen, it was weighed to determine the moisture and then removed from the containers to examine its friability. The measurements for friability were adopted as follows:

(1) Solid (A) The frozen material did not break after being dropped three or more times on the iron plate.

(2) Solid (B) Broke the second time it was dropped.

(3) Solid (C) Broke the first time it was dropped.

(4) Solid (D) Very friable solid, crumbling with slight pressure.

(5) Solid (E) Very loosely adhering particles.

(6) Solid (F) No perceptible effect in freezing.

It is not claimed that the degree of solidity thus determined is an exact point. Points for the various tests indicate a rough comparison only, sufficiently accurate for the purpose of this experiment.

The freezing tests were made on each size for moisture contents at or below the percentage of retained moisture after natural drainage. The percentages of retained moisture after drainage were determined from the curve, page 63 , and are as follows: - run of mine, 14.1%; 1½ to 1 inch, 5.9%; 1 to ½ inch, 5.6%; ½ to ¼ inch, 5.3%; ¼ inch to 8 mesh, 6.6%; through 8 mesh, 15.8%.

The percentage of moisture in each sample of frozen coal was then calculated as a percentage of the percentage of moisture retained after natural drainage. These percentages for all the freezing tests on each size were then plotted against the degree of solidity. The resulting graph is shown on page 68.

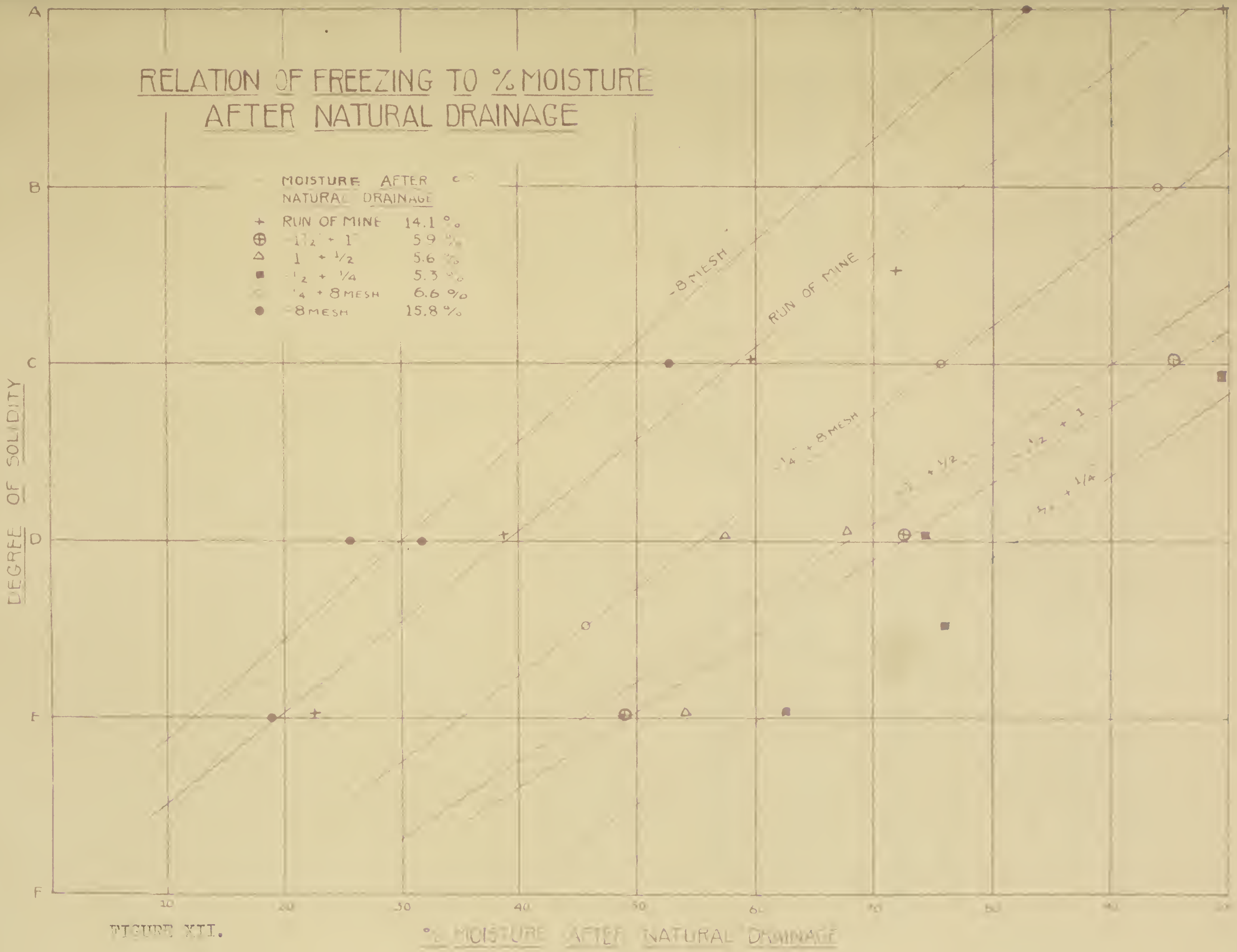

RELATION OF FREEZING TO % MOISTURE
AFTER NATURAL DRAINAGE
MOISTURE AFTER
NATURAL DRAINAGE
+ RUN OF MINE 14.1 %
⊕ -1 1/2 + 1" 5.9 %
△ 1 + 1/2 5.6 %
■ -1/2 + 1/4 5.3 %
○ -1/4 + 8 MESH 6.6 %
● -8 MESH 15.8 %
-8 MESH
RUN OF MINE
-1/4 + 8 MESH
1 + 1/2
1 1/2 + 1
1/2 + 1/4
A
B
C
D
E
F
DEGREE OF SOLIDITY
10
20
30
40
50
60
70
80
90
% MOISTURE AFTER NATURAL DRAINAGE

FIGURE XII.

Conclusion.

The run of mine samples and those of the fines through 8 mesh give the most continuous series of results. The larger sizes at 100% retained moisture are less solidly frozen than the fines, and this relation is proportionately the same for lower percentages of retained moisture.

The solidity values at D for the various sizes would likely indicate the maximum percentages of retained moistures which would be permissible if trouble is to be avoided from freezing. Natural drainage alone will not reduce the moisture sufficiently in any of these sizes, and therefore it would seem necessary for a wet washing plant, operating in Alberta during the winter, to use drying equipment on their product to prevent freezing troubles during storage or shipment.

CHAPTER IX.

EFFECT OF CLEANING ON THE FUSIBILITY OF ASH.

In an investigation of the coals of Canada carried out at McGill University several years ago, E. Stansfield[12] fused the ash from several washed coals and found that the fusion temperature was raised by the washing process.

Scroggie[9] made determinations on four Alberta coals at the University of Alberta in 1924, and found that in some cases the fusion temperature was raised and in others it was lowered, as follows:

Sample	Ash Reduction	Softening Temperature Change	Softening Interval
Greenhill	17.4% to 12.2%	Both not fused	No conclusion
Luscar	16.1% to 7.8%	+ 40 degrees C.	+ 50 degrees C
Sterling	18.8% to 10.2%	- 5 " "	- 35 " "
Three Hills	13.5% to 6.2%	- 245 " "	- 155 " "
Sterling	20.3% to 18.8%	+ 110 " "	+ 70 " "

Estep[10] plotted the fusion temperatures of the ash of a large number of coals against the percentage ash and found that there was no apparent relation.

Messrs. Sinnatt and Wood[11] investigated the melting point of ash from the different kinds of coal in a seam and found that the ash of dull coal had a higher melting point than the ash of bright coal and of mother coal. They state that excessive purification may produce coal yielding ash the melting point of which is relatively low, and thus reduce the value of the

purified coal for certain industrial purposes.

Yancey and Fraser[16] tested twelve samples of United States coal to discover the effect of washing, at certain yields, upon the fusing point of the ash. Eight of the washed coals had higher ash-softening temperatures than the raw coals from which they were obtained, and two were lower. With two coals there was no change.

The fusibility of any ash depends upon the kind and the number of acids and bases present, as well as on the equivalent proportions of the acids and bases. Any readjustment by cleaning is necessarily likely to materially change the fusibility.

Method Used.

The method of determining the fusibility of ash as used in the Research Council Laboratory, is an adaptation of the A.S.T.M. procedure (2). The ash is prepared by burning the coal sample in a muffle furnace, grinding to pass a 200 mesh screen and then repeating the burning in the muffle furnace with a current of oxygen passing through it. The ash is molded into cones 3/4" in height and mounted on a ½" square base of refractory material.

The cones are heated in a mildly reducing atmosphere in a No. 3 Melter's Furnace made by the American Furnace Company, in which some 22 cones may be held at once. The temperature of the cones is measured by means of a thermocouple. Each batch of cones in the furnace is heated to a certain temperature, with the rate of rise controlled to be from 5 to 10 degrees C. per minute. As soon as this temperature is reached, the furnace is cooled and the cones withdrawn. Subsequent groups are heated to temperatures successively higher at 25°C intervals. The resulting series of cones is a permanent record for each ash sample of the changes of shape, color, etc. during fusion. Three

stages in melting may be noted:

(1) Initial deformation, when the tip of the cone becomes rounded or commences to bend over.

(2) Softening temperature, when the cone has melted to a spherical shape.

(3) Fluid temperature, when the ash has become completely fluid and melted down even with the base.

Ash Fusion Results for Washing Tests.

Five of the coals tested for washability were investigated to discover the effect of cleaning on the fusion of ash. The float and sink fractions of the washability tests were combined for each coal in the correct proportions to give composite samples of all the sizes representative of the following fractions; (1) run of mine, (2) float at 1.36 specific gravity, (3) float at 1.48 specific gravity, (4) float at 1.55 specific gravity, (5) sink at 1.55 specific gravity. These samples were then reduced to ash and tested for fusibility in the manner described.

The following table indicates the percentage of material floating at each of the specific gravities for which the samples were considered.

Specific Gravity	Brazeau	Coalspur	Mountain Park	Luscar	Coleman
1.36	52	24	71	86	42
1.48	77	72	93	95	80
1.55	86	78	94	96	88

The fusibility series for each group of coals have been shown in the accompanying photographs. The cones are arranged in rows according to the sample taken, and vertically according to increasing temperature intervals as indicated. Comparisons of the different ash fusion temperatures may be easily made.

(1) Brazeau, page 74. The ash in the float at 1.36 specific gravity was dark brown in colour and showed some surface change at 1350°C. with a rapid fusion between 1450 and 1500°C. There was a slight indication of change in the 1.48 float sample at the highest temperature, but the other samples were unaffected.

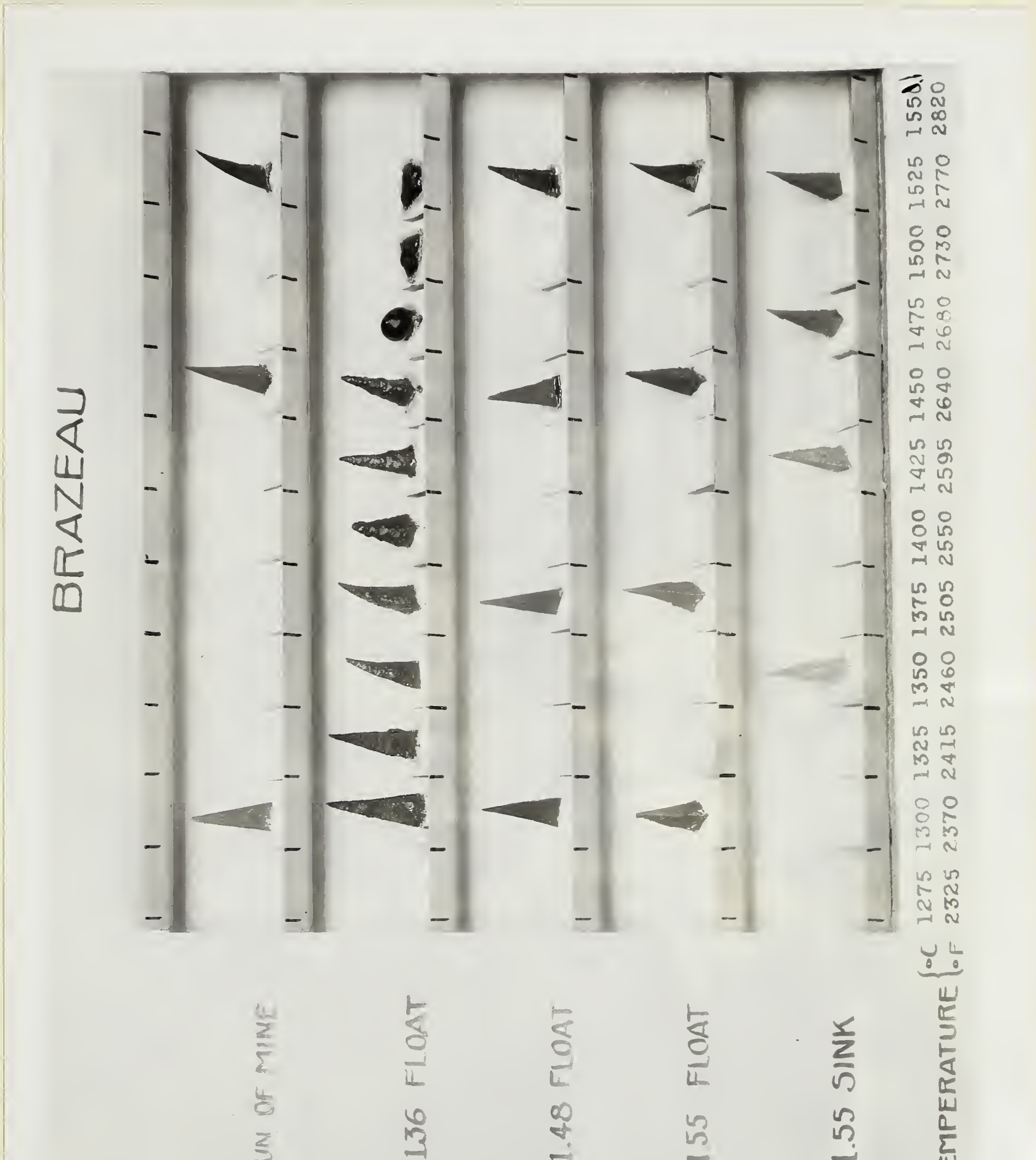
Although commercial cleaning would lower the fusing point of the ash in this coal, it would not be lowered enough to give trouble.

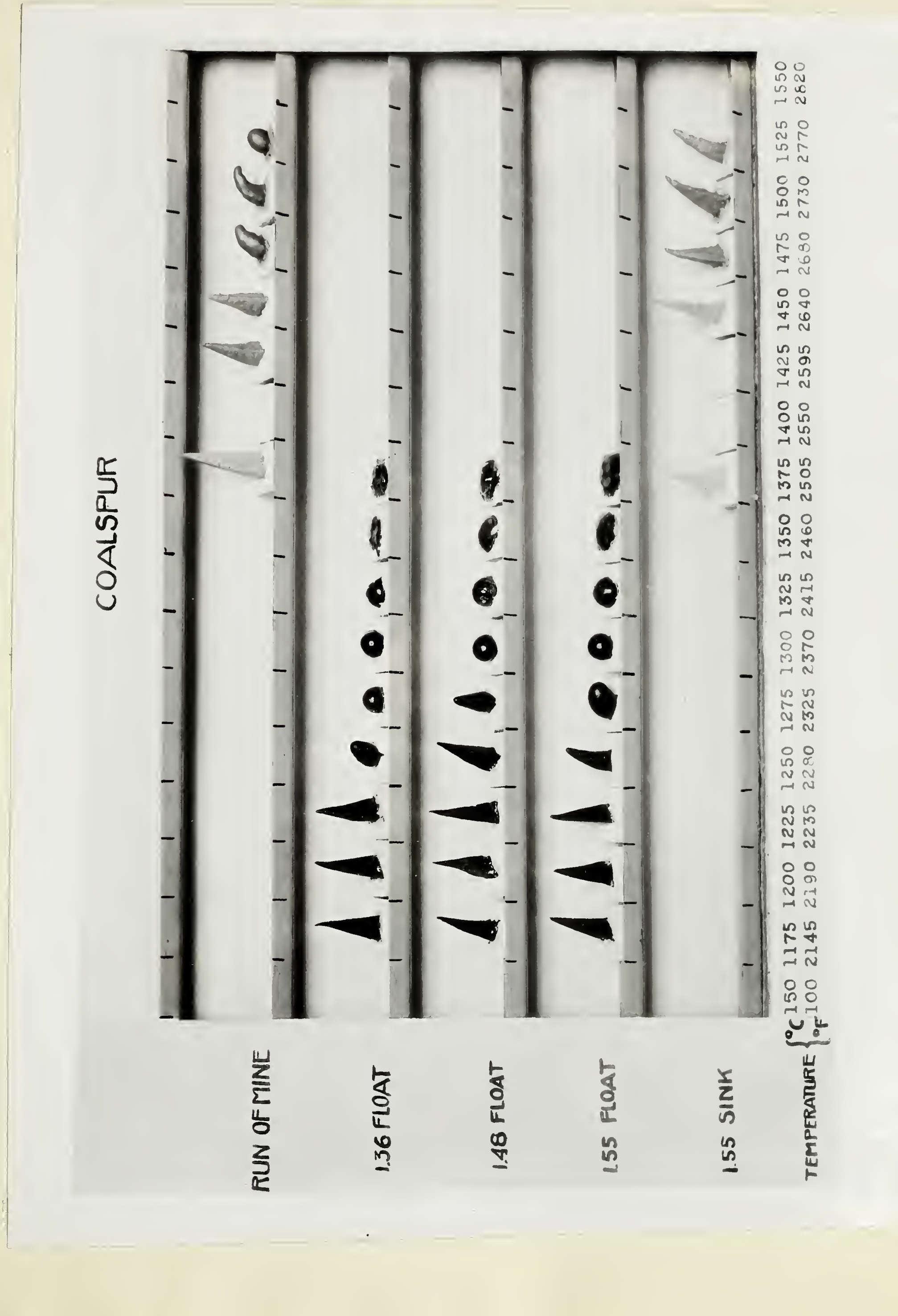
(2) Coalspur, page 75. The contrast between the light colored ash from the run of mine and sink samples, and the dark ash from the float samples, is very marked. The softening temperatures of the ash in the cleaned fractions were between 1275 and 1300°C. The softening temperature for the run of mine was 1525°C, while the refuse temperature was little affected even at that temperature. With this coal, cleaning lowered the temperature of ash fusion about two hundred degrees. There was also a tendency for the 1.55 float ash to soften at a temperature lower than the ash in the cleaner floats, so that the fusion temperatures were irregularly affected by the degree of cleaning.

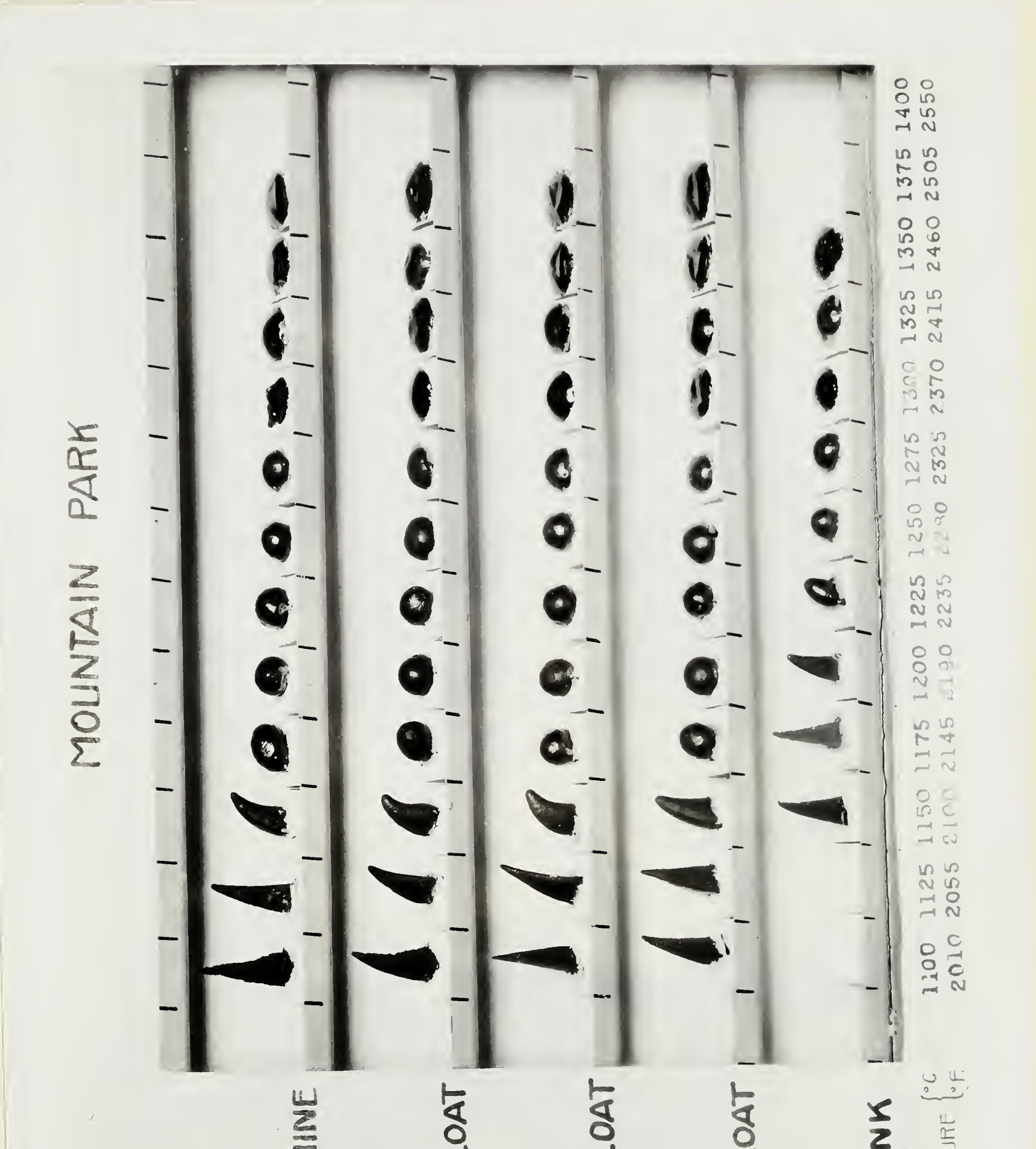
(3) Mountain Park, page 76. The ash samples from all fractions of this coal were brown in colour with that from the refuse slightly the lighter. The ash for run of mine and the three fractions floating showed initial deformations between 1125 and 1150°C., softening temperatures at 1175°C., and fluid temperatures at 1300-1350°C. The ash for the 1.55 sink had a fluid temperature similar to the other samples, but differed in having a much higher softening temperature.

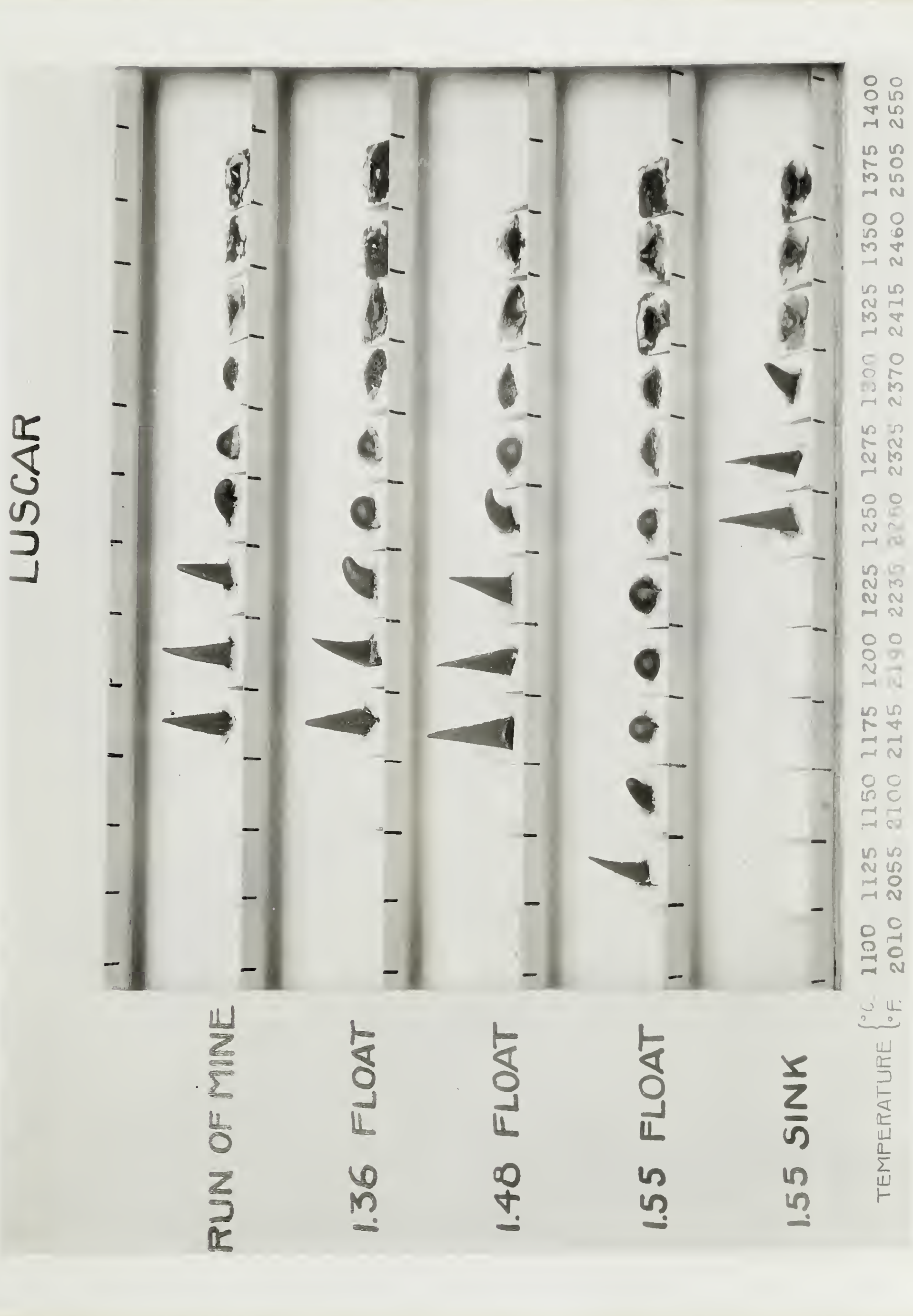
The tests show that cleaning would result in little change in the fusibility of the ash.

(4) Luscar, page 77. The ashes of the fractions in this coal are characterized by dark colour and by short interval between the softening and


BRAZEAU
RUN OF MINE
1.36 FLOAT
1.48 FLOAT
1.55 FLOAT
1.55 SINK
TEMPERATURE °C 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550
°F 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820


COALSPUR
RUN OF MINE
1.36 FLOAT
1.48 FLOAT
1.55 FLOAT
1.55 SINK
TEMPERATURE °C 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550
°F 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820


MOUNTAIN PARK
RUN OF MINE
1.36 FLOAT
1.48 FLOAT
1.55 FLOAT
1.55 SINK
TEMPERATURE °C 1100 1125 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400
°F 2010 2055 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550


LUSCAR
RUN OF MINE
1.36 FLOAT
1.48 FLOAT
1.55 FLOAT
1.55 SINK
TEMPERATURE
°C 1100 1125 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400
°F 2010 2055 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550

the fluid temperatures, probably on account of the presence of iron compounds. The 1.36 float ash had a softening temperature 25°C. lower than the ash from the run of mine coal. The 1.48 float ash was about the same as that of the original run of mine. The 1.55 float ash was exceptional in that it had a softening temperature 125°C. lower than that of the original ash.

Cleaning might lower the ash fusion temperature of this coal.

(5) Coleman, page 79. The ash samples of this coal were all light grey in colour. Only the ash from the cleanest fraction (1.36 float) showed any tendency to soften at the highest temperature used.

The ash in this coal would thus not be affected to any great extent by cleaning.

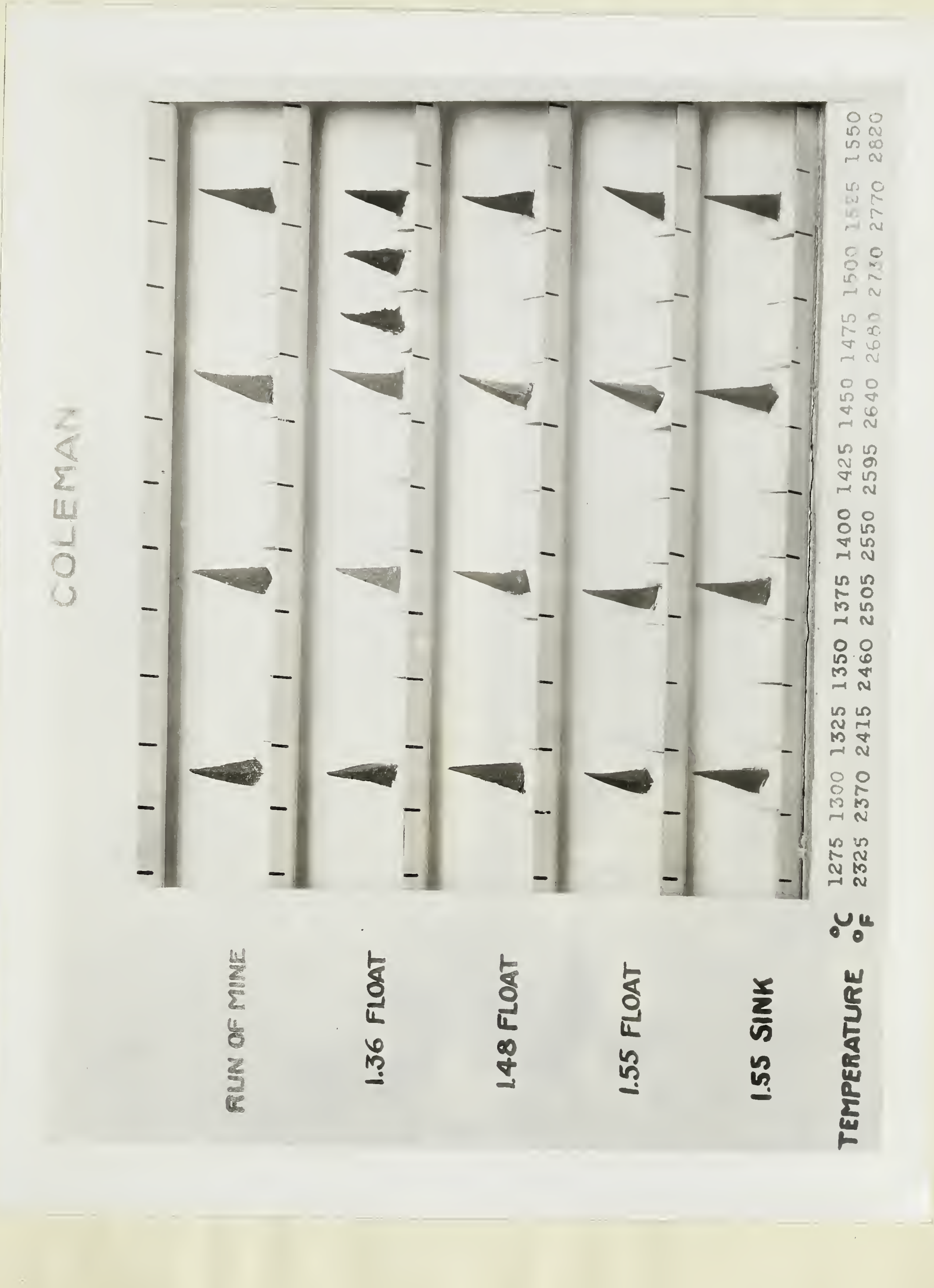
Comparison of Softening Temperatures.

Coal	Run of mine	1.36 Float	1.48 Float	1.55 Float	1.55 Sink	Effect of Cleaning on the Fusibility of Ash
Brazeau	*	1475	*	*	*	Lowered
Coalspur	1525	1275	1300	1300	*	Lowered
Mountain Park	1200	1175	1175	1175	1250	Lowered slightly
Luscar	1260	1250	1260	1175	1310	Lowered
Coleman	*	(indication of change)	*	*	*	Lowered slightly

* above 1525°C

Ash Fusion for Selected Lumps of Coal.

An investigation was made of the fusibility of the ash in selected lumps of coal obtained from a specific gravity ash investigation. This was done as it was clear that it would also give suggestive information as to the


COLEMAN
RUN OF MINE
1.36 FLOAT
1.48 FLOAT
1.55 FLOAT
1.55 SINK
TEMPERATURE °C 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550
°F 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820

possible influence of cleaning the coal on the fusibility of the ash. The following groups of samples were examined: (1) Hillcrest, (2) Brazeau, (3) Luscar, (4) Beazer.

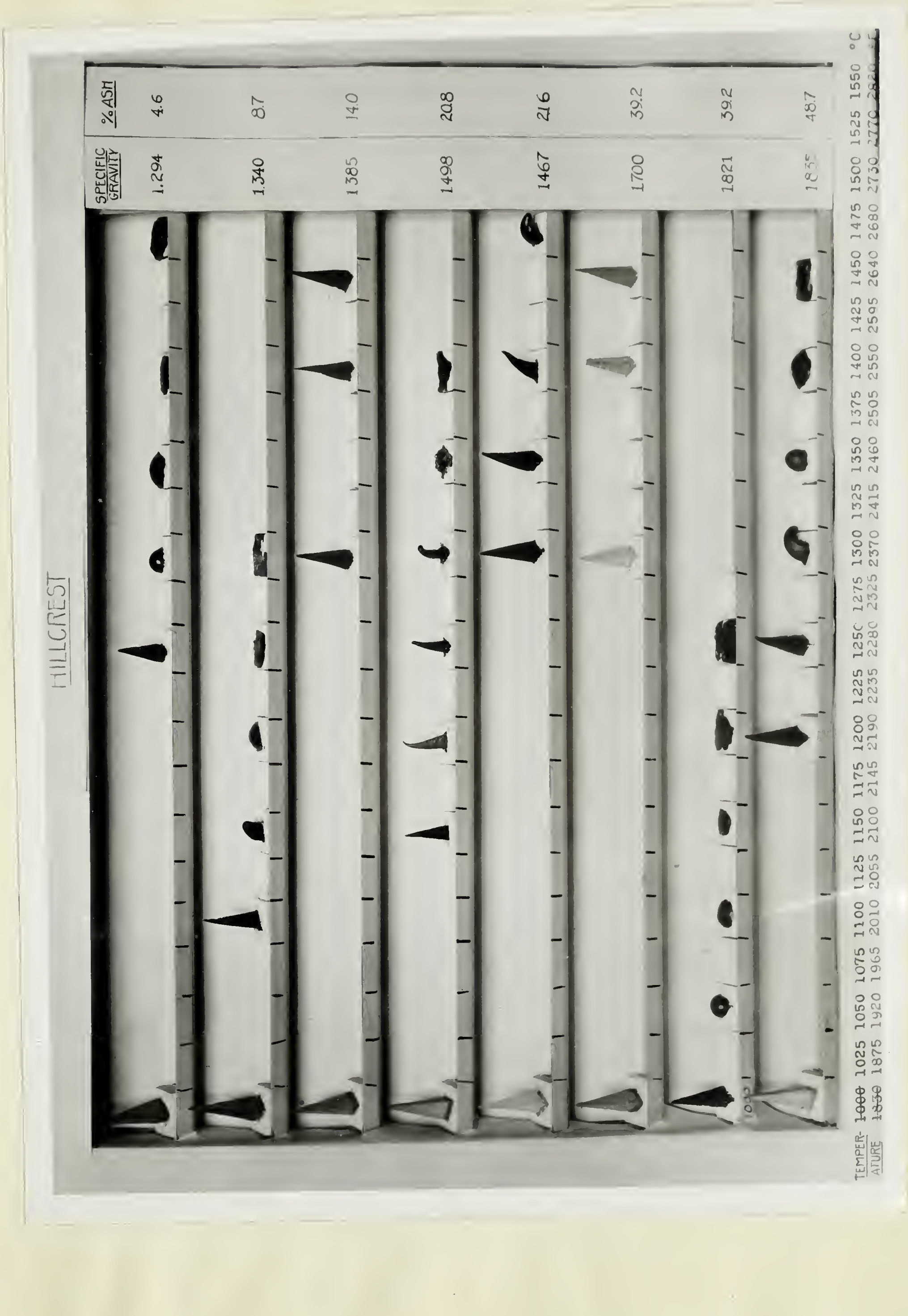
The ash cones of those samples were treated similarly to those obtained from washing tests, except that the temperature intervals were 50 degrees instead of 25 degrees C. The fusibility series are shown in the accompanying photographs in horizontal rows from top to bottom in order of increasing percentage ash of the selected lump.

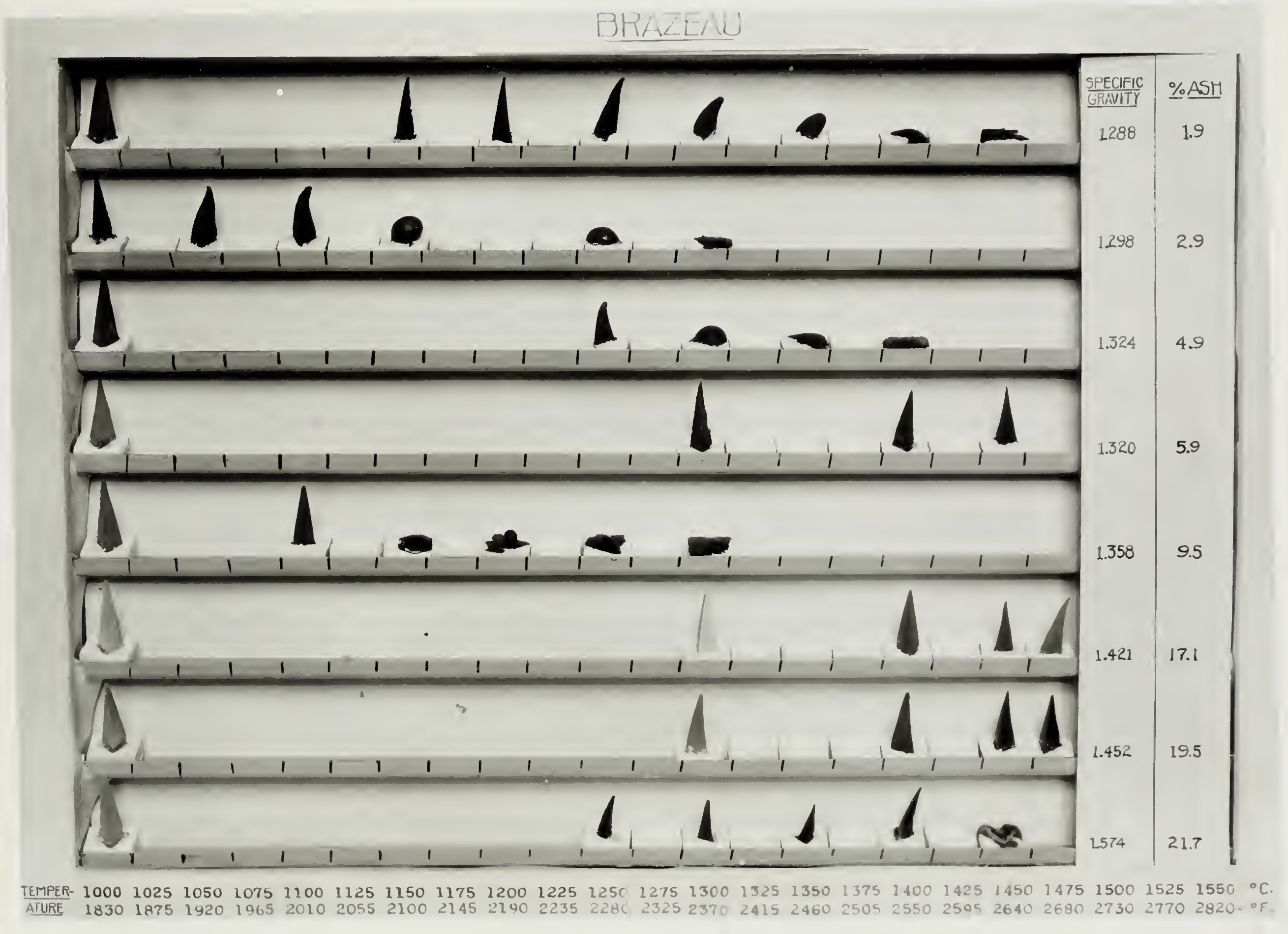
(1) Hillcrest, page 81. The fusion of ash from eight selected lumps of this coal shows that there is no direct relation with percentage ash. The ash of one lump at 39.2% ash showed no change at 1450 degrees C., while another with the same percentage ash, but apparently of different composition began to change at 1025 degrees C. There is a very wide range of fusibility shown in this series.

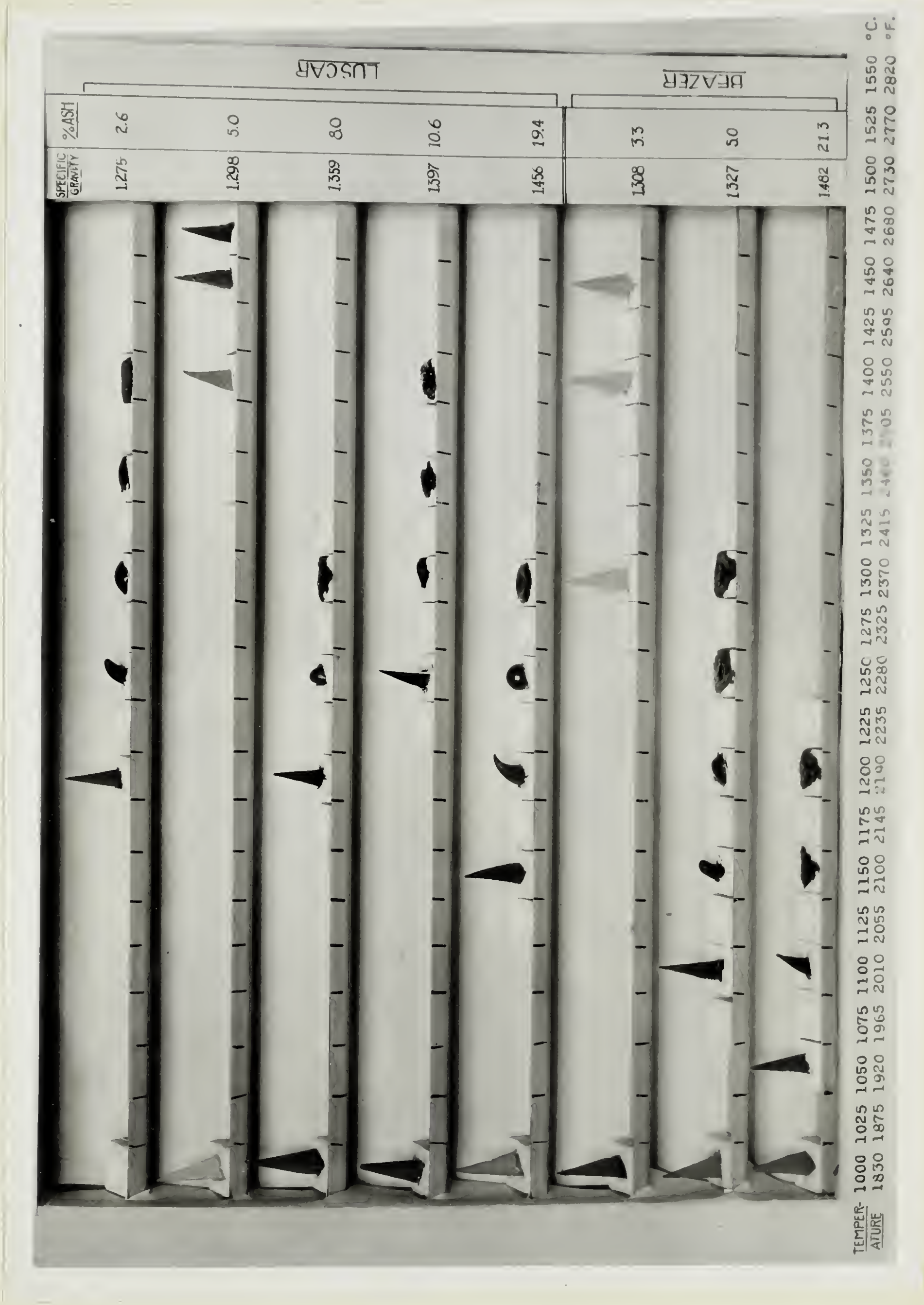
(2) Brazeau, page 82. This group of ash also indicates no relation between percentage ash and fusibility. One lump with 1.9% ash has a softening temperature at 1375 degrees C., while others with increasing ash have lower and higher softening temperatures. A tendency toward shorter intervals between softening and fluid temperatures is noticeable in the lumps of higher percentage ash. The observed range of fusibility is not quite so high as with Hillcrest.

(3) Luscar, page 83. There is a tendency in four out of five lumps of Luscar coal toward lower fusion temperatures with increasing ash percentage. The observed range of fusibility is slightly less than for Brazeau.

(4) Beazer, page 83. This group, like that of Luscar, showed a


HILLCREST
SPECIFIC GRAVITY
% ASH
1.294
4.6
1.340
8.7
1.385
14.0
1.498
20.8
1.467
21.6
1.700
39.2
1.821
39.2
1.835
48.7
TEMPER-ATURE
~~1000~~ 1025 1050 1075 1100 1125 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550 °C
~~1830~~ 1875 1920 1965 2010 2055 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820 °F


BRAZEAU
SPECIFIC GRAVITY
% ASH
1.288
1.9
1.298
2.9
1.324
4.9
1.320
5.9
1.358
9.5
1.421
17.1
1.452
19.5
1.574
21.7
TEMPERATURE
1000 1025 1050 1075 1100 1125 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550 °C.
1830 1875 1920 1965 2010 2055 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820 °F.


LUSCAR
BEAZER
SPECIFIC GRAVITY
% ASH
1.275 2.6
1.298 5.0
1.359 8.0
1.397 10.6
1.456 19.4
1.308 3.3
1.327 5.0
1.482 21.3
TEMPER-ATURE
1000 1025 1050 1075 1100 1125 1150 1175 1200 1225 1250 1275 1300 1325 1350 1375 1400 1425 1450 1475 1500 1525 1550 °C.
1830 1875 1920 1965 2010 2055 2100 2145 2190 2235 2280 2325 2370 2415 2460 2505 2550 2595 2640 2680 2730 2770 2820 °F.

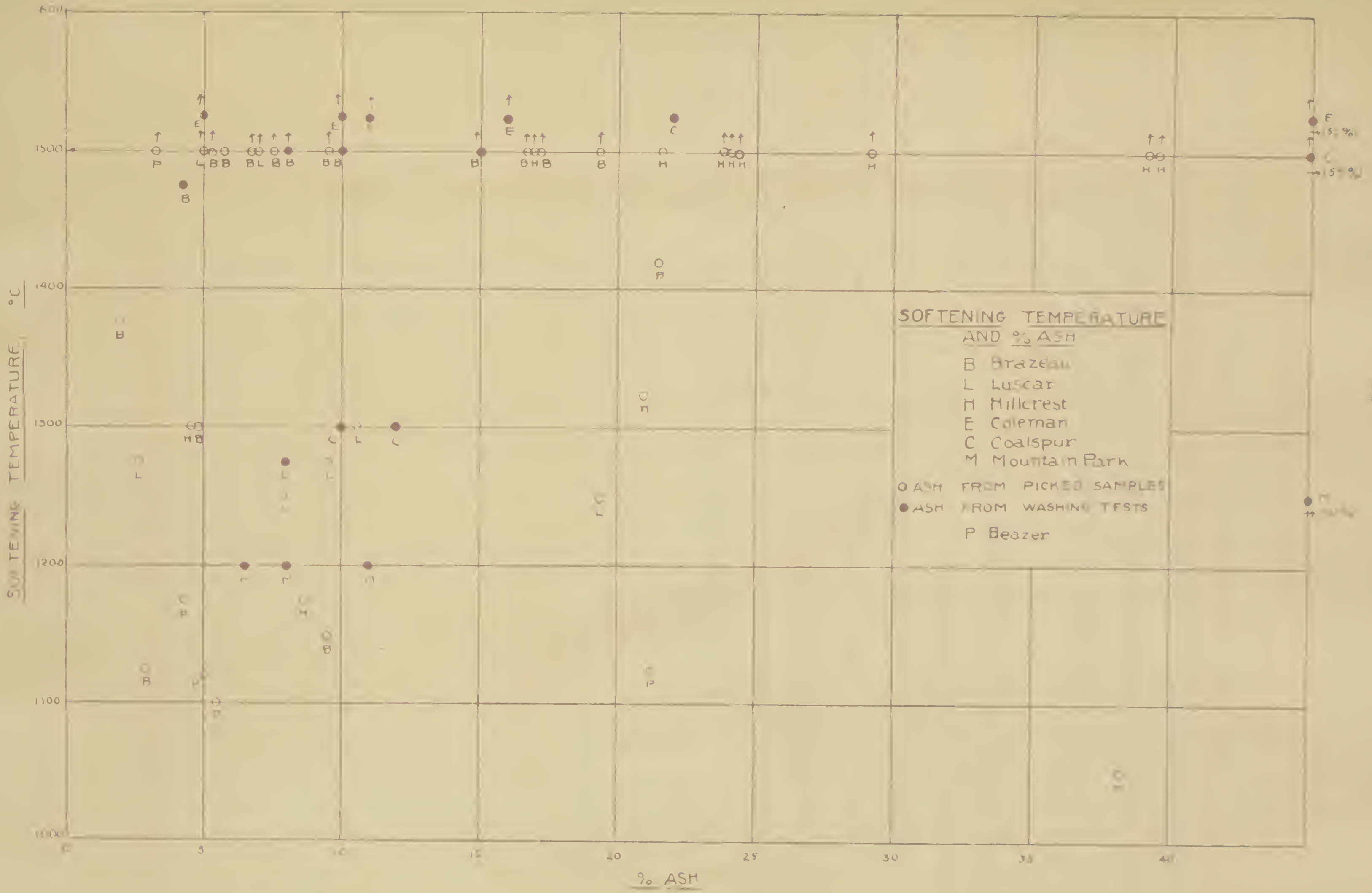

SOFTENING TEMPERATURE AND % ASH
B Brazeau
L Luscar
H Hillcrest
E Coleman
C Coalspur
M Mountain Park
○ ASH FROM PICKED SAMPLES
● ASH FROM WASHING TESTS
P Beazer
SOFTENING TEMPERATURE °C
% ASH
1600
1500
1400
1300
1200
1100
1000
0
5
10
15
20
25
30
35
40
(15.9%)
(15.9%)

FIGURE XXI.

tendency toward lowerd fusibility with increasing percentage ash.

The percentage of ash was plotted against the respective softening temperatures of all the ash samples tested. That no apparent relation exists is evident from the position of the points so obtained, page 84.

Summary of Ash Fusion Results.

The Hillcrest and Brazeau groups showed no relation between their percentage ash and fusibility temperatures of individual lumps. Luscar and Beazer showed a slight tendency toward lowered fusibility with increasing percentage ash. The work confirms our knowledge that coal ash is a very complex mixture of different constituents, the proportions of which vary from lump to lump in the same coal, so that a wide range of fusing temperatures may occur even of lumps which have the same percentage ash.

SUMMARY.

(1) The advantages of using and shipping cleaned coal were discussed with relation to Alberta coals.

(2) Float and sink tdsts were carried out on six coals presenting typical cleaning problems, and modifications of the usual float and sink methods were developed.

(3) The float and sink data was expressed graphically by a new method to show the percentage reduction of ash, percentage loss of clean coal, etc., and the specific gravity distribution for each coal and the most important sizes in each.

(4) An attempt was made to give a practical interpretation of cleaning data by means of the washability curves.

(5) Experimental work was carried out to find the natural rate of drainage for wet coal in several sizes of coal.

(6) The degree of friability of frozen wet coal was determined for several moisture contents and the data related to the rate of natural drainage.

(7) Ash fusion determinations were made on the ash from samples of cleaned coal. It was found that there was a tendency toward lower fusibility with decreasing ash content.

(8) Ash samples from selected lumps of coal were tested for fusibility, and a wide range of fusion temperatures found.

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